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**UTILITY  
PATENT APPLICATION  
TRANSMITTAL**

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	ACU 109 DIV(2)
First Inventor	Julie Straub
Title	Porous Drug Matrices and Methods of Manufacture Thereof
Express Mail Label No.	EL 690 662 580 US

**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original and a duplicate for fee processing)
2. ☒ Applicant claims small entity status.  
See 37 CFR 1.27.
3. ☒ Specification [Total Pages 41]  
(preferred arrangement set forth below)
  - Descriptive title of the invention
  - Cross Reference to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to sequence listing, a table, or a computer program listing appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 4]
5. Oath or Declaration [Total Pages 4]
  - a. ☐ Newly executed (original or copy)
  - b. ☒ Copy from a prior application (37 CFR 1.63 (d))  
(for continuation/divisional with Box 17 completed)
    - i. ☐ **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ Application Data Sheet. See 37 CFR 1.76

**ADDRESS TO:** Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

7. ☐ CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - a. ☐ Computer Readable Form (CRF)
  - b. Specification Sequence Listing on:
    - i. ☐ CD-ROM or CD-R (2 copies); or
    - ii. ☐ paper
  - c. ☐ Statements verifying identity of above copies

**ACCOMPANYING APPLICATION PARTS**

9. ☐ Assignment Papers (cover sheet & document(s))
10. ☒ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
11. ☐ English Translation Document (if applicable)
12. ☒ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
13. ☒ Preliminary Amendment
14. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. ☒ Other: Check for \$355.00

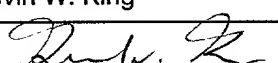
17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation ☒ Divisional ☐ Continuation-in-part (CIP)of prior application No.: 09 / 433,486Prior application information: Examiner Webman, E.Group / Art Unit: 1617

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

**18. CORRESPONDENCE ADDRESS**☒ Customer Number or Bar Code Labelor ☒ Correspondence address below

Name	Patrea L. Pabst Arnall Golden & Gregory, LLP				
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Signature		Date Nov. 3, 2000	

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ACU 109 DIV(2) 20435/42

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# FEE TRANSMITTAL for FY 2000

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT (\$355.00)

## Complete if Known

Application Number	Divisional of 09/433,486
Filing Date	November 3, 2000
First Named Inventor	Julie Straub
Examiner Name	
Group Art Unit	
Attorney Docket No.	ACU 109 DIV(2)

## METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number: 01-2507  
Deposit Account Name: Amall Golden & Gregory

☒ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

☒ Applicant claims small entity status. See 37 CFR 1.27

2. ☒ Payment Enclosed:

☒ Check ☐ Credit card ☐ Money Order ☐ Other

## FEE CALCULATION

### 1. BASIC FILING FEE

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
101 710	201 355	Utility filing fee	355.00
106 320	206 160	Design filing fee	
107 490	207 245	Plant filing fee	
108 710	208 355	Reissue filing fee	
114 150	214 75	Provisional filing fee	

SUBTOTAL (1) (\$355.00)

### 2. EXTRA CLAIM FEES

Total Claims: 13  
Independent Claims: 1  
Multiple Dependent: 0

Extra Claims: 0  
Fee from below: 0  
Fee Paid: 0

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description
103 18	203 9	Claims in excess of 20
102 80	202 40	Independent claims in excess of 3
104 270	204 135	Multiple dependent claim, if not paid
109 80	209 40	** Reissue independent claims over original patent
110 18	210 9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$0)

## FEE CALCULATION (continued)

### 3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105 130	205 65	Surcharge - late filing fee or oath	
127 50	227 25	Surcharge - late provisional filing fee or cover sheet	
139 130	139 130	Non-English specification	
147 2,520	147 2,520	For filing a request for ex parte reexamination	
112 920*	112 920*	Requesting publication of SIR prior to Examiner action	
113 1,840*	113 1,840*	Requesting publication of SIR after Examiner action	
115 110	215 55	Extension for reply within first month	
116 390	216 195	Extension for reply within second month	
117 890	217 445	Extension for reply within third month	
118 1,390	218 695	Extension for reply within fourth month	
128 1,890	228 945	Extension for reply within fifth month	
119 310	219 155	Notice of Appeal	
120 310	220 155	Filing a brief in support of an appeal	
121 270	221 135	Request for oral hearing	
138 1,510	138 1,510	Petition to institute a public use proceeding	
140 110	240 55	Petition to revive - unavoidable	
141 1,240	241 620	Petition to revive - unintentional	
142 1,240	242 620	Utility issue fee (or reissue)	
143 440	243 220	Design issue fee	
144 600	244 300	Plant issue fee	
122 130	122 130	Petitions to the Commissioner	
123 50	123 50	Petitions related to provisional applications	
126 240	126 240	Submission of Information Disclosure Stmt	
581 40	581 40	Recording each patent assignment per property (times number of properties)	
146 710	246 355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149 710	249 355	For each additional invention to be examined (37 CFR § 1.129(b))	
179 710	279 355	Request for Continued Examination (RCE)	
169 900	169 900	Request for expedited examination of a design application	

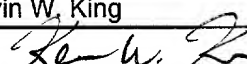
Other fee (specify)

\* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$)

## SUBMITTED BY

Complete (if applicable)

Name (Print/Type)	Kevin W. King	Registration No. (Attorney/Agent)	42,737	Telephone	(404) 873-8596
Signature		Date	Nov. 3, 2000		

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ACU 109 DIV(2) 20435/42

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Applicants: Julie Straub, Howard Bernstein, Donald E. Chickering, III,  
Sarwat Khattak, and Greg Randall

Serial No.: Divisional of U.S.S.N. 09/433,486

Express Mail Label  
No. EL 690 662 580 US

Filed: November 3, 2000

Date of Deposit:  
November 3, 2000

For: POROUS DRUG MATRICES AND METHODS OF MANUFACTURE  
THEREOF

Box Patent Application  
Assistant Commissioner for Patents  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT**

Sir:

Prior to examination, please amend the application as follows.

**In the Specification**

On page 1, line 5, please delete "Priority is claimed", and insert --This is a divisional of  
U.S. application Serial No. 09/433,486, filed November 4, 1999, which claims priority-- in place  
thereof.

**In the Claims**

Please cancel claims 1-22.

Please amend the claims as follows:

23. (Once amended) A method of delivering a drug to a patient in need thereof, comprising

administering a therapeutically or prophylactically effective amount of the drug in a formulation comprising a porous matrix [formed of] which comprises a wetting agent and microparticles of the drug, wherein the microparticles have a mean diameter between about 0.1 and 5  $\mu\text{m}$  and a total surface area greater than about  $0.5 \text{ m}^2/\text{mL}$ , and wherein the [dry] porous matrix [is in a dry powder form having] has a TAP density less than or equal to  $1.0 \text{ g/mL}$  and/or [having] has a total surface area of greater than or equal to  $0.2 \text{ m}^2/\text{g}$  and is in the form of a dry powder.

25. (Once amended) The method of claim 24 wherein the parenteral route is selected from the group consisting of [intravenous,] intravenous, intraarterial, intracardiac, intrathecal, intraosseous, intraarticular, intrasynovial, intracutaneous, subcutaneous, and intramuscular administration.

32. (Once amended) The method of claim 23 wherein the formulation is [a dry powder] suitable for pulmonary administration.

Please add the following new claims:

--33. The method of claim 23 wherein the dry powder form of the porous matrix has a TAP density less than or equal to  $1.0 \text{ g/mL}$ .--

--34. The method of claim 23 wherein the dry powder form of the porous matrix has a total surface area of greater than or equal to  $0.2 \text{ m}^2/\text{g}$ .--

Divisional of U.S.S.N. 09/433,486  
"Porous Drug Matrices and Methods for Manufacture Thereof"  
By: Julie Straub, Howard Bernstein, Donald E. Chickering, III,  
Sarwat Khattak, and Greg Randall  
Express Mail Label No.: EL 690 662 580 US  
Date of Deposit: November 3, 2000  
**PRELIMINARY AMENDMENT**

--35. The method of claim 23 wherein the mean diameter of the microparticles is between about 0.5 and 5  $\mu\text{m}$ .--

### Remarks

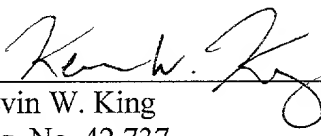
Claims 1-22, which were the subject of a restriction requirement in the parent application, have been canceled. Claims 23, 25, and 32 have been amended to clarify the claimed invention, and to correct spelling and antecedent basis of the claims. New claims 33-35 have been added. Support for new claims 33 and 34 is found, for example, in claim 1 as originally filed, and support for new claim 35 is found, for example, at page 5, lines 28-30. No new matter has been added. A copy of the claims as amended is provided in the attached Appendix for the convenience of the Examiner.

The invention defined by the claims utilizes a porous matrix having drug particles dispersed therein. The matrix is a porous matrix wherein the porosity is defined by the TAP density of the material ( $\leq 1.0 \text{ g/mL}$ ) and having a surface area  $\geq 0.2 \text{ m}^2/\text{g}$ . The drug particles are defined as having a diameter between 0.1 and 5  $\mu\text{m}$  and a total surface area greater than 0.5  $\text{m}^2/\text{mL}$ .

Divisional of U.S.S.N. 09/433,486  
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Express Mail Label No.: EL 690 662 580 US  
Date of Deposit: November 3, 2000  
**PRELIMINARY AMENDMENT**

Examination and allowance of claims 23-35 is respectfully requested.

Respectfully submitted,

  
\_\_\_\_\_  
Kevin W. King  
Reg. No. 42,737

Date: November 3, 2000

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## APPENDIX

### *Claims as Preliminarily Amended*

1-22. (Canceled).

23. (Once amended) A method of delivering a drug to a patient in need thereof, comprising

administering a therapeutically or prophylactically effective amount of the drug in a formulation comprising a porous matrix [formed of] which comprises a wetting agent and microparticles of the drug, wherein the microparticles have a mean diameter between about 0.1 and 5  $\mu\text{m}$  and a total surface area greater than about 0.5  $\text{m}^2/\text{mL}$ , and wherein the [dry] porous matrix [is in a dry powder form having] has a TAP density less than or equal to 1.0  $\text{g/mL}$  and/or [having] has a total surface area of greater than or equal to 0.2  $\text{m}^2/\text{g}$  and is in the form of a dry powder.

24. The method of claim 23 wherein the formulation is suitable for administration by a route selected from the group consisting of parenteral, mucosal, oral, and topical administration.

25. (Once amended) The method of claim 24 wherein the parenteral route is selected from the group consisting of [intravenous,] intravenous, intraarterial, intracardiac, intrathecal, intraosseous, intraarticular, intrasynovial, intracutaneous, subcutaneous, and intramuscular administration.

26. The method of claim 24 wherein the mucosal route is selected from the group consisting of pulmonary, buccal, sublingual, intranasal, rectal, and vaginal administration.

27. The method of claim 23 wherein the formulation is suitable for intraocular or conjunctival administration.

28. The method of claim 23 wherein the formulation is suitable for intracranial, intralesional, or intratumoral administration.

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Date of Deposit: November 3, 2000  
**PRELIMINARY AMENDMENT**

29. The method of claim 23 wherein the formulation is in an aqueous solution suitable for parenteral administration.

30. The method of claim 23 wherein the formulation is in a tablet or capsule suitable for oral administration.

31. The method of claim 23 wherein the formulation is in a suppository suitable for vaginal or rectal administration.

32. (Once amended) The method of claim 23 wherein the formulation is [a dry powder] suitable for pulmonary administration.

33. (New) The method of claim 23 wherein the dry powder form of the porous matrix has a TAP density less than or equal to 1.0 g/mL.

34. (New) The method of claim 23 wherein the dry powder form of the porous matrix has a total surface area of greater than or equal to 0.2 m<sup>2</sup>/g.

35. (New) The method of claim 23 wherein the mean diameter of the microparticles is between about 0.5 and 5 µm.



**APPLICATION**  
**FOR**  
**UNITED STATES LETTERS PATENT**

**BY**  
**JULIE STRAUB**  
**HOWARD BERNSTEIN**  
**DONALD E. CHICKERING III**  
**SARWAT KHATTAK**  
**AND**  
**GREG RANDALL**

**FOR**  
**POROUS DRUG MATRICES AND**  
**METHODS OF MANUFACTURE THEREOF**

# **POROUS DRUG MATRICES AND METHODS OF MANUFACTURE THEREOF**

## **Cross-Reference To Related Applications**

5           Priority is claimed to U.S. provisional applications Serial No. 60/136,323, filed May 27, 1999, and Serial No. 60/158,659, filed October 8, 1999.

## **Background of the Invention**

10           This invention generally relates to formulations of drugs, especially drugs having low solubility, and more particularly to methods of making formulations of such drugs to enhance their rate of dissolution.

          The bioavailability of a drug can be limited by poor dissolution of the drug into aqueous bodily fluids following administration. This rate-limiting step  
15           may therefore be critical to rapidly attaining therapeutically effective drug levels.

          Traditional approaches to parenteral delivery of poorly soluble drugs include using large volumes of aqueous diluents, solubilizing agents, detergents, non-aqueous solvents, or non-physiological pH solutions. These formulations,  
20           however, can increase the systemic toxicity of the drug composition or damage body tissues at the site of administration.

          Other approaches have focused on the physical form of the drug itself. Since the dissolution rate of a drug particle is directly related to its surface area available to contact the aqueous media at the site of administration or site of  
25           absorption, methods of preparing drugs in nanoparticulate form have been developed in an effort to maximize the drug surface area, as described, for example, in U.S. Patent No. 5,534,270 to De Castro and U.S. Patent No. 5,587,143 to Wong. Nanoparticles, however, can be difficult to produce and maintain in a stable form due to the tendency of the nanoparticles to flocculate  
30           or agglomerate, particularly without the presence of surface modifying agents

adsorbed or coated onto the particles. Furthermore, milling or wet grinding techniques, which are typically employed for nanonization, can be undesirable, as it can take several days to process a single batch, scaling-up of the milling or grinding process can be difficult and/or costly, the process can be difficult to  
5 conduct aseptically, and it is difficult to eliminate shedding of milling media into the product.

Other efforts directed at enhancing the rate of dissolution have focused on delivering the drug as a dispersion in a water-soluble or biodegradable matrix, typically in the form of polymeric microparticles. For example, the  
10 dissolution rate of dexamethasone reportedly was improved by entrapping the drug in chitosan microspheres made by spray-drying (Genta, et al., *S.T.P. Pharma Sciences* 5(3):202-07 (1995)). Similarly, others have reported enhanced dissolution rates by mixing a poorly soluble drug powder with a water-soluble gelatin, which purportedly makes the surface of the drug hydrophilic (Imai, et  
15 al., *J. Pharm. Pharmacol.*, 42:615-19 (1990)).

Related efforts have been directed to forming relatively large, porous matrices of low solubility drugs. For example, Roland & Paeratakul, "Spherical Agglomerates of Water-Insoluble Drugs," *J. Pharma. Sci.*, 78(11):964-67  
(1989) discloses preparing beads having a low solubility drug content up to  
20 98%, wherein the beads have a porous internal structure. Such large beads, however, are unsuitable for parenteral administration, and the beads have less surface area and slower dissolution rates than smaller particles.

It is therefore an object of the present invention to provide compositions enhancing the dissolution rate of drugs, especially drugs having low aqueous  
25 solubility, and to provide methods of making such compositions.

It is another object of the present invention to provide compositions providing enhanced dissolution of drugs, especially drugs of low aqueous solubility, in a formulation suitable for administration by a variety of routes, including, but not limited to, parenteral, mucosal, oral, and topical  
30 administration, for local, regional, or systemic effect.

It is further object of the present invention to provide compositions for administration as a bolus injection instead of by infusion.

### Summary of the Invention

- 5           Drugs are provided in a porous matrix form wherein the dissolution rate of the drug is enhanced when the matrix is contacted with an aqueous medium. In a preferred embodiment, low aqueous solubility drugs are provided in a porous matrix form which forms microparticles when the matrix is contacted with an aqueous medium. The porous matrix with low aqueous solubility drugs
- 10       yields upon contact with an aqueous medium microparticles having a mean diameter between about 0.1 and 5  $\mu\text{m}$  and a total surface area greater than about 0.9  $\text{m}^2/\text{mL}$ . The dry porous matrix is in a dry powder form having a TAP density less than or equal to 1.0  $\text{g/mL}$  and/or having a total surface area (sum of internal and external surface area) of greater than or equal to 0.2  $\text{m}^2/\text{g}$ .
- 15       The porous matrices that contain the drug are preferably made using a process that includes (i) dissolving a drug in a volatile solvent to form a drug solution, (ii) combining at least one pore forming agent with the drug solution to form an emulsion, suspension, or second solution, and (iii) removing the volatile solvent and pore forming agent from the emulsion, suspension, or second solution to
- 20       yield the dry porous matrix of drug. The resulting porous matrix has a faster rate of dissolution following administration to a patient, as compared to non-porous matrix forms of the drug. The pore forming agent can be either a volatile liquid that is immiscible with the drug solvent or a volatile solid compound, preferably a volatile salt. If the pore forming agent is a liquid, the agent is
- 25       emulsified with the drug solution. If the pore forming agent is a solid, the agent is (i) dissolved in the drug solution, (ii) dissolved in a solvent that is not miscible in the drug solvent and then emulsified with the drug solution, or (iii) suspended as solid particulates in the drug solution. Optionally, hydrophilic excipients, wetting agents, and/or tonicity agents may be added to the drug solvent, the pore
- 30       forming agent solvent, or both. The solution, emulsion, or suspension of the

pore forming agent in the drug solution is then processed to remove the drug solvent and the pore forming agent, as well as any pore forming agent solvent. In a preferred embodiment, spray drying, optionally followed by lyophilization, fluid bed drying, or vacuum drying, is used to remove the solvents and the pore forming agent.

An advantage of the formulations is that they can be administered as a bolus, when the drug normally must be infused to avoid precipitation of the drug. By avoiding precipitation of drug *in vivo*, the formulations can also be administered parenterally. An additional advantage is the formulations can be administered in reduced volumes.

In one embodiment, the matrix further includes a pegylated excipient, such as pegylated phospholipid, with the drug. The pegylated excipient shields the drug from macrophage uptake, which prolong its half-life or enhance bioavailability of the drug.

In a preferred embodiment, the porous drug matrix is reconstituted with an aqueous medium and administered parenterally, such as intramuscularly, subcutaneously, or intravenously. Alternatively, the porous drug matrix can be further processed using standard techniques into tablets or capsules for oral administration or into rectal suppositories, delivered using a dry powder inhaler for pulmonary administration, or mixed/processed into a cream or ointment for topical administration.

### Brief Description of the Drawings

Figure 1 is a graph of the *in vitro* dissolution rate (percent dissolved versus time) for non-formulated prednisone and prednisone in porous matrix form.

Figure 2 is a graph of the *in vitro* dissolution rate (percent dissolved versus time) for non-formulated griseofulvin and griseofulvin in porous matrix form.

Figure 3 is a graph of the *in vitro* dissolution rate (percent dissolved

versus time) for non-formulated nifedipine and nifedipine in porous matrix form.

Figure 4 is a graph of the *in vitro* dissolution rate (percent dissolved versus time) for non-formulated naproxen and naproxen in a porous matrix form.

Figure 5 is a graph of the *in vitro* dissolution rate (percent dissolved versus time) for non-formulated paclitaxel and paclitaxel in a porous matrix form.

Figure 6 is a graph of the *in vitro* dissolution rate (percent dissolved versus time) for various porous matrix forms of nifedipine.

Figure 7 is a graph of the *in vitro* dissolution rate (percent dissolved versus time) for various porous matrix forms of griseofulvin.

Figure 8 is a graph of nifedipine plasma levels versus time post intravenous administration of reconstituted nifedipine matrix in dogs.

## Detailed Description of the Invention

The rate of dissolution of drugs can be enhanced by making the drug into a porous matrix form, substantially increasing the surface area of the drug available to contact aqueous biological fluids at the site of administration of the drug composition. In a preferred embodiment, the drug has low aqueous solubility.

### I. Drug Matrix Compositions

The porous drug matrix is at least 1 to 95%, preferably at least about 10%, and more preferably between about 10 and 60%, drug by weight. The matrices also may contain hydrophilic excipients such as water soluble polymers or sugars, wetting agents such as surfactants, and tonicity agents.

The form of the drug matrix (drug powder) is critical to the dissolution rate. The matrix must contain microparticles of drug, which preferably have a diameter between about 100 nm and 5  $\mu$ m, more preferably between about 500 nm and 5  $\mu$ m. The average total surface area of the microparticles contained

within the porous matrix, which typically is in the form of a dry powder, is 0.9 m<sup>2</sup>/mL or greater. Total surface area values can be determined using standard Coulter Counter equipment and techniques.

The drug matrix must be sufficiently porous to yield microparticles having these parameters. Measurements useful in characterizing the porosity of the drug matrix are the bulk density or the transaxial pressure (“TAP”) density of the dry porous matrix (dry powder) and the total surface area (sum of internal and external surface area) of the dry porous matrix. The TAP density preferably is less than about 1.0 g/ml, more preferably less than 0.8 g/ml. This level of porosity of the matrix, characterized by density, provides sufficient surface area to enhance wetting of the dry porous matrix and enhance drug dissolution. The total surface area of the porous matrix can be measured, for example, by BET surface area analysis. The total surface area of the porous matrix preferably is greater than 0.1 m<sup>2</sup>/g, more preferably greater than or equal to 0.2 m<sup>2</sup>/g. This level of total surface area provides sufficient surface area to enhance wetting of the dry porous matrix and enhance drug dissolution.

### 1. Drugs

A wide variety of drugs are useful in the methods and compositions described herein. In a preferred embodiment, the drug is a low aqueous solubility drug. As used herein, the term “low aqueous solubility” means that the drug has a solubility of less than about 10 mg/mL, and preferably less than about 5 mg/mL, in aqueous media at approximately physiological temperatures and pH. As used herein, the term “drug” refers to chemical or biological molecules providing a therapeutic, diagnostic, or prophylactic effect *in vivo*.

Drugs contemplated for use in the compositions described herein include the following categories and examples of drugs and alternative forms of these drugs such as alternative salt forms, free acid forms, free base forms, and hydrates:

analgesics/antipyretics (e.g., aspirin, acetaminophen, ibuprofen, naproxen sodium, buprenorphine, propoxyphene hydrochloride, propoxyphene napsylate,

- meperidine hydrochloride, hydromorphone hydrochloride, morphine, oxycodone, codeine, dihydrocodeine bitartrate, pentazocine, hydrocodone bitartrate, levorphanol, diflunisal, trolamine salicylate, nalbuphine hydrochloride, mefenamic acid, butorphanol, choline salicylate, butalbital,
- 5 phenyltoloxamine citrate, diphenhydramine citrate, methotrimeprazine, cinnamedrine hydrochloride, and meprobamate);
- antiasmatics (e.g., ketotifen and traxanox);
- antibiotics (e.g., neomycin, streptomycin, chloramphenicol, cephalosporin, ampicillin, penicillin, tetracycline, and ciprofloxacin);
- 10 antidepressants (e.g., nefopam, oxyperline, doxepin, amoxapine, trazodone, amitriptyline, maprotiline, phenelzine, desipramine, nortriptyline, tranlycypromine, fluoxetine, doxepin, imipramine, imipramine pamoate, isocarboxazid, trimipramine, and protriptyline);
- antidiabetics (e.g., biguanides and sulfonylurea derivatives);
- 15 antifungal agents (e.g., griseofulvin, ketoconazole, itraconazole, amphotericin B, nystatin, and candicidin);
- antihypertensive agents (e.g., propranolol, propafenone, oxyprenolol, nifedipine, reserpine, trimethaphan, phenoxybenzamine, pargyline hydrochloride, deserpidine, diazoxide, guanethidine monosulfate, minoxidil, rescinnamine,
- 20 sodium nitroprusside, rauwolfia serpentina, alseroxylon, and phentolamine );
- anti-inflammatories (e.g., (non-steroidal) indomethacin, ketoprofen, flurbiprofen, naproxen, ibuprofen, ramifenazone, piroxicam, (steroidal) cortisone, dexamethasone, fluazacort, celecoxib, rofecoxib, hydrocortisone, prednisolone, and prednisone);
- 25 antineoplastics (e.g., cyclophosphamide, actinomycin, bleomycin, daunorubicin, doxorubicin, epirubicin, mitomycin, methotrexate, fluorouracil, carboplatin, carmustine (BCNU), methyl-CCNU, cisplatin, etoposide, camptothecin and derivatives thereof, phenesterine, paclitaxel and derivatives thereof, docetaxel and derivatives thereof, vinblastine, vincristine, tamoxifen, and pipsulfan);
- 30 antianxiety agents (e.g., lorazepam, buspirone, prazepam, chlordiazepoxide,



oxazepam, clorazepate dipotassium, diazepam, hydroxyzine pamoate, hydroxyzine hydrochloride, alprazolam, droperidol, halazepam, chlormezanone, and dantrolene);

immunosuppressive agents (e.g., cyclosporine, azathioprine, mizoribine, and

5 FK506 (tacrolimus));

antimigraine agents (e.g., ergotamine, propanolol, isometheptene mucate, and dichloralphenazone);

sedatives/hypnotics (e.g., barbiturates such as pentobarbital, pentobarbital, and secobarbital; and benzodiazepines such as flurazepam hydrochloride, triazolam,

10 and midazolam);

antianginal agents (e.g., beta-adrenergic blockers; calcium channel blockers such as nifedipine, and diltiazem; and nitrates such as nitroglycerin, isosorbide dinitrate, pentaerythritol tetranitrate, and erythrityl tetranitrate);

antipsychotic agents (e.g., haloperidol, loxapine succinate, loxapine

15 hydrochloride, thioridazine, thioridazine hydrochloride, thiothixene, fluphenazine, fluphenazine decanoate, fluphenazine enanthate, trifluoperazine, chlorpromazine, perphenazine, lithium citrate, and prochlorperazine);

antimanic agents (e.g., lithium carbonate);

antiarrhythmics (e.g., bretylium tosylate, esmolol, verapamil, amiodarone,

20 encainide, digoxin, digitoxin, mexiletine, disopyramide phosphate, procainamide, quinidine sulfate, quinidine gluconate, quinidine polygalacturonate, flecainide acetate, tocainide, and lidocaine);

antiarthritic agents (e.g., phenylbutazone, sulindac, penicillamine, salsalate, piroxicam, azathioprine, indomethacin, meclofenamate, gold sodium thiomalate,

25 ketoprofen, auranofin, aurothioglucose, and tolmetin sodium);

antigout agents (e.g., colchicine, and allopurinol);

anticoagulants (e.g., heparin, heparin sodium, and warfarin sodium);

thrombolytic agents (e.g., urokinase, streptokinase, and alteplase);

antifibrinolytic agents (e.g., aminocaproic acid);

30 hemorheologic agents (e.g., pentoxifylline);

- antiplatelet agents (e.g., aspirin);
- anticonvulsants (e.g., valproic acid, divalproex sodium, phenytoin, phenytoin sodium, clonazepam, primidone, phenobarbital, carbamazepine, amobarbital sodium, methsuximide, metharbital, mephobarbital, mephentyoin,
- 5 phensuximide, paramethadione, ethotoin, phenacemide, secobarbital sodium, clorazepate dipotassium, and trimethadione);
- antiparkinson agents (e.g., ethosuximide);
- antihistamines/antipruritics (e.g., hydroxyzine, diphenhydramine, chlorpheniramine, brompheniramine maleate, cyproheptadine hydrochloride,
- 10 terfenadine, clemastine fumarate, triprolidine, carbinoxamine, diphenylpyraline, phenindamine, azatadine, tripeleminamine, dexchlorpheniramine maleate, methdilazine, and);
- agents useful for calcium regulation (e.g., calcitonin, and parathyroid hormone);
- antibacterial agents (e.g., amikacin sulfate, aztreonam, chloramphenicol, chloramphenicol palmitate, ciprofloxacin, clindamycin, clindamycin palmitate,
- 15 clindamycin phosphate, metronidazole, metronidazole hydrochloride, gentamicin sulfate, lincomycin hydrochloride, tobramycin sulfate, vancomycin hydrochloride, polymyxin B sulfate, colistimethate sodium, and colistin sulfate);
- antiviral agents (e.g., interferon alpha, beta or gamma, zidovudine, amantadine
- 20 hydrochloride, ribavirin, and acyclovir);
- antimicrobials (e.g., cephalosporins such as cefazolin sodium, cephradine, cefaclor, cephalirin sodium, ceftizoxime sodium, cefoperazone sodium, cefotetan disodium, cefuroxime e azotil, cefotaxime sodium, cefadroxil monohydrate, cephalixin, cephalothin sodium, cephalixin hydrochloride
- 25 monohydrate, cefamandole nafate, cefoxitin sodium, cefonicid sodium, ceforanide, ceftriaxone sodium, ceftazidime, cefadroxil, cephradine, and cefuroxime sodium; penicillins such as ampicillin, amoxicillin, penicillin G benzathine, cyclacillin, ampicillin sodium, penicillin G potassium, penicillin V potassium, piperacillin sodium, oxacillin sodium, bacampicillin hydrochloride,
- 30 cloxacillin sodium, ticarcillin disodium, azlocillin sodium, carbenicillin indanyl

- sodium, penicillin G procaine, methicillin sodium, and nafcillin sodium;  
erythromycins such as erythromycin ethylsuccinate, erythromycin, erythromycin  
estolate, erythromycin lactobionate, erythromycin stearate, and erythromycin  
ethylsuccinate; and tetracyclines such as tetracycline hydrochloride, doxycycline  
5 hyclate, and minocycline hydrochloride, azithromycin, clarithromycin)  
anti-infectives (e.g., GM-CSF);  
bronchodilators (e.g., sympathomimetics such as epinephrine hydrochloride,  
metaproterenol sulfate, terbutaline sulfate, isoetharine, isoetharine mesylate,  
isoetharine hydrochloride, albuterol sulfate, albuterol, bitolterolmesylate,  
10 isoproterenol hydrochloride, terbutaline sulfate, epinephrine bitartrate,  
metaproterenol sulfate, epinephrine, and epinephrine bitartrate; anticholinergic  
agents such as ipratropium bromide; xanthines such as aminophylline,  
dyphylline, metaproterenol sulfate, and aminophylline; mast cell stabilizers such  
as cromolyn sodium; inhalant corticosteroids such as beclomethasone  
15 dipropionate (BDP), and beclomethasone dipropionate monohydrate;  
salbutamol; ipratropium bromide; budesonide; ketotifen; salmeterol; xinafoate;  
terbutaline sulfate; triamcinolone; theophylline; nedocromil sodium;  
metaproterenol sulfate; albuterol; flunisolide; fluticasone propionate  
steroidal compounds and hormones (e.g., androgens such as danazol,  
20 testosterone cypionate, fluoxymesterone, ethyltestosterone, testosterone  
enanthate, methyltestosterone, fluoxymesterone, and testosterone cypionate;  
estrogens such as estradiol, estropipate, and conjugated estrogens; progestins  
such as methoxyprogesterone acetate, and norethindrone acetate; corticosteroids  
such as triamcinolone, betamethasone, betamethasone sodium phosphate,  
25 dexamethasone, dexamethasone sodium phosphate, dexamethasone acetate,  
prednisone, methylprednisolone acetate suspension, triamcinolone acetonide,  
methylprednisolone, prednisolone sodium phosphate, methylprednisolone  
sodium succinate, hydrocortisone sodium succinate, triamcinolone  
hexacetonide, hydrocortisone, hydrocortisone cypionate, prednisolone,  
30 fludrocortisone acetate, paramethasone acetate, prednisolone tebutate,

- prednisolone acetate, prednisolone sodium phosphate, and hydrocortisone sodium succinate; and thyroid hormones such as levothyroxine sodium);  
hypoglycemic agents (e.g., human insulin, purified beef insulin, purified pork insulin, glyburide, chlorpropamide, glipizide, tolbutamide, and tolazamide);  
5 hypolipidemic agents (e.g., clofibrate, dextrothyroxine sodium, probucol, pravastatin, atorvastatin, lovastatin, and niacin);  
proteins (e.g., DNase, alginase, superoxide dismutase, and lipase);  
nucleic acids (e.g., sense or anti-sense nucleic acids encoding any therapeutically useful protein, including any of the proteins described herein);  
10 agents useful for erythropoiesis stimulation (e.g., erythropoietin);  
antiulcer/antireflux agents (e.g., famotidine, cimetidine, and ranitidine hydrochloride);  
antinauseants/antiemetics (e.g., meclizine hydrochloride, nabilone, prochlorperazine, dimenhydrinate, promethazine hydrochloride,  
15 thiethylperazine, and scopolamine);  
oil-soluble vitamins (e.g., vitamins A, D, E, K, and the like);  
as well as other drugs such as mitotane, halonitrosoureas, anthrocyclines, and ellipticine. A description of these and other classes of useful drugs and a listing of species within each class can be found in Martindale, *The Extra*  
20 *Pharmacopoeia, 30th Ed.* (The Pharmaceutical Press, London 1993), the disclosure of which is incorporated herein by reference in its entirety.

- Examples of other drugs useful in the compositions and methods described herein include ceftriaxone, ketoconazole, ceftazidime, oxaprozin, albuterol, valacyclovir, urofollitropin, famciclovir, flutamide, enalapril,  
25 mefformin, itraconazole, buspirone, gabapentin, fosinopril, tramadol, acarbose, lorazepam, follitropin, glipizide, omeprazole, fluoxetine, lisinopril, tramadol, levofloxacin, zafirlukast, interferon, growth hormone, interleukin, erythropoietin, granulocyte stimulating factor, nizatidine, bupropion, perindopril, erbumine, adenosine, alendronate, alprostadil, benazepril, betaxolol,  
30 bleomycin sulfate, dexfenfluramine, diltiazem, fentanyl, flecainid, gemcitabine,

- glatiramer acetate, granisetron, lamivudine, mangafodipir trisodium, mesalamine, metoprolol fumarate, metronidazole, miglitol, moexipril, monteleukast, octreotide acetate, olopatadine, paricalcitol, somatropin, sumatriptan succinate, tacrine, verapamil, nabumetone, trovafloxacin,
- 5 dolasetron, zidovudine, finasteride, tobramycin, isradipine, tolcapone, enoxaparin, fluconazole, lansoprazole, terbinafine, pamidronate, didanosine, diclofenac, cisapride, venlafaxine, troglitazone, fluvastatin, losartan, imiglucerase, donepezil, olanzapine, valsartan, fexofenadine, calcitonin, and ipratropium bromide. These drugs are generally considered to be water soluble.
- 10 Preferred drugs include albuterol, adapalene, doxazosin mesylate, mometasone furoate, ursodiol, amphotericin, enalapril maleate, felodipine, nefazodone hydrochloride, valrubicin, albendazole, conjugated estrogens, medroxyprogesterone acetate, nicardipine hydrochloride, zolpidem tartrate, amlodipine besylate, ethinyl estradiol, omeprazole, rubitecan, amlodipine
- 15 besylate/ benazepril hydrochloride, etodolac, paroxetine hydrochloride, paclitaxel, atovaquone, felodipine, podofilox, paricalcitol, betamethasone dipropionate, fentanyl, pramipexole dihydrochloride, Vitamin D<sub>3</sub> and related analogues, finasteride, quetiapine fumarate, alprostadil, candesartan, cilexetil, fluconazole, ritonavir, busulfan, carbamazepine, flumazenil, risperidone,
- 20 carbamazepine, carbidopa, levodopa, ganciclovir, saquinavir, amprenavir, carboplatin, glyburide, sertraline hydrochloride, rofecoxib carvedilol, halobetasolpropionate, sildenafil citrate, celecoxib, chlorthalidone, imiquimod, simvastatin, citalopram, ciprofloxacin, irinotecan hydrochloride, sparfloxacin, efavirenz, cisapride monohydrate, lansoprazole, tamsulosin hydrochloride,
- 25 mofafinil, clarithromycin, letrozole, terbinafine hydrochloride, rosiglitazone maleate, diclofenac sodium, lomefloxacin hydrochloride, tirofiban hydrochloride, telmisartan, diazepam, loratadine, toremifene citrate, thalidomide, dinoprostone, mefloquine hydrochloride, trandolapril, docetaxel, mitoxantrone hydrochloride, tretinoin, etodolac, triamcinolone acetate, estradiol.
- 30 ursodiol, nelfinavir mesylate, indinavir, beclomethasone dipropionate,

oxaprozin, flutamide, famotidine, nifedipine, prednisone, cefuroxime, lorazepam, digoxin, lovastatin, griseofulvin, naproxen, ibuprofen, isotretinoin, tamoxifen citrate, nimodipine, amiodarone, and alprazolam.

## 2. Excipients

5           The matrices may contain hydrophilic excipients such as water soluble polymers or sugars which can serve as bulking agents or as wetting agents, wetting agents such as surfactants or sugars, and tonicity agents. Upon contact with an aqueous medium, water penetrates through the highly porous matrix to dissolve the water soluble excipients in the matrix. In the case of low aqueous  
10           solubility drugs, a suspension of drug particles in the aqueous medium is left. The total surface area of the resultant low aqueous solubility drug microparticles is increased relative to the unprocessed drug and the dissolution rate of the drug is increased.

          One of skill in the art can select appropriate excipients for use in the drug  
15           matrix compositions, considering a variety of factors, such as the drug to be administered, the route of administration, the dosage, and the preferred dissolution rate. For example, the excipients can function as bulking agents, release-modifiers, wetting agents, tonicity agents, or combinations thereof. Preferred excipients include hydrophilic polymers, wetting agents, and sugars.  
20           The amount of excipient in the drug matrix is less than about 95%, more preferably less than about 80%, by weight of the drug matrix.

          The hydrophilic excipients, wetting agents, and tonicity agents may be added to the drug solution, the pore forming agent, or both, during production of the matrix.

### 25                           (i) Hydrophilic Polymers

          The polymers that can be used in the drug matrices described herein include both synthetic and natural polymers, either non-biodegradable or biodegradable. Representative synthetic polymers include polyethylene glycol ("PEG"), polyvinyl pyrrolidone, polymethacrylates, polylysine, poloxamers,  
30           polyvinyl alcohol, polyacrylic acid, polyethylene oxide, and polyethyloxazoline.

Representative natural polymers include albumin, alginate, gelatin, acacia, chitosan, cellulose dextran, ficoll, starch, hydroxyethyl cellulose, hydroxypropyl cellulose, hydroxy-propylmethyl cellulose, hyaluronic acid, carboxyethyl cellulose, carboxymethyl cellulose, deacetylated chitosan, dextran sulfate, and derivatives thereof. Preferred hydrophilic polymers include PEG, polyvinyl pyrrolidone, poloxamers, hydroxypropyl cellulose, and hydroxyethyl cellulose.

The hydrophilic polymer selected for use in a particular drug matrix formulation is based on a variety of factors, such as the polymer molecular weight, polymer hydrophilicity, and polymer inherent viscosity. The hydrophilic polymer can be used as a bulking agent or as a wetting agent.

(ii) Sugars

Representative sugars that can be used in the drug matrices include mannitol, sorbitol, xylitol, glucitol, ducitol, inositol, arabinitol; arabitol, galactitol, iditol, allitol, fructose, sorbose, glucose, xylose, trehalose, allose, dextrose, altrose, gulose, idose, galactose, talose, ribose, arabinose, xylose, lyxose, sucrose, maltose, lactose, lactulose, fucose, rhamnose, melezitose, maltotriose, and raffinose. Preferred sugars include mannitol, lactose, sucrose, sorbitol, trehalose, glucose, and are adjusted to provide osmolality if administered parenterally or to provide wetting of the porous drug matrix or the drug microparticles within the matrix.

(iii) Wetting Agents

Wetting agents can be used to facilitate water ingress into the matrix and wetting of the drug particles in order to facilitate dissolution.

Representative examples of wetting agents include gelatin, casein, lecithin (phosphatides), gum acacia, cholesterol, tragacanth, stearic acid, benzalkonium chloride, calcium stearate, glycerol monostearate, cetostearyl alcohol, cetomacrogol emulsifying wax, sorbitan esters, polyoxyethylene alkyl ethers (e.g., macrogol ethers such as cetomacrogol 1000), polyoxyethylene castor oil derivatives, polyoxyethylene sorbitan fatty acid esters (e.g., TWEEN<sup>TM</sup>s), polyethylene glycols, polyoxyethylene stearates, colloidal silicon

dioxide, phosphates, sodium dodecylsulfate, carboxymethylcellulose calcium, carboxymethylcellulose sodium, methylcellulose, hydroxyethylcellulose, hydroxy propylcellulose, hydroxypropylmethylcellulose phthlate, noncrystalline cellulose, magnesium aluminum silicate, triethanolamine, polyvinyl alcohol, and  
5 polyvinylpyrrolidone (PVP). Tyloxapol (a nonionic liquid polymer of the alkyl aryl polyether alcohol type, also known as superinone or triton) is another useful wetting agent. Most of these wetting agents are known pharmaceutical excipients and are described in detail in the Handbook of Pharmaceutical  
10 The Pharmaceutical Society of Great Britain (The Pharmaceutical Press, 1986).

Preferred wetting agents include polyvinylpyrrolidone, polyethylene glycol, tyloxapol, poloxamers such as PLURONIC<sup>TM</sup> F68, F127, and F108, which are block copolymers of ethylene oxide and propylene oxide, and polyamines such as TETRONIC<sup>TM</sup> 908 (also known as POLOXAMINE<sup>TM</sup>  
15 908), which is a tetrafunctional block copolymer derived from sequential addition of propylene oxide and ethylene oxide to ethylenediamine (available from BASF), dextran, lecithin, dialkylesters of sodium sulfosuccinic acid such as AEROSOL<sup>TM</sup> OT, which is a dioctyl ester of sodium sulfosuccinic acid (available from American Cyanimid), DUPONOL<sup>TM</sup> P, which is a sodium lauryl  
20 sulfate (available from DuPont), TRITON<sup>TM</sup> X-200, which is an alkyl aryl polyether sulfonate (available from Rohm and Haas), TWEEN<sup>TM</sup> 20 and TWEEN<sup>TM</sup> 80, which are polyoxyethylene sorbitan fatty acid esters (available from ICI Specialty Chemicals), Carbowax 3550 and 934, which are polyethylene glycols (available from Union Carbide), Crodesta F-110, which is  
25 a mixture of sucrose stearate and sucrose distearate, and Crodesta SL-40 (both available from Croda Inc.), and SA90HCO, which is  $C_{18}H_{37}-CH_2(CON(CH_3)CH_2(CHOH)_4CH_2OH)_2$ .

Wetting agents which have been found to be particularly useful include Tetronic 908, the Tweens, Pluronic F-68 and polyvinylpyrrolidone. Other  
30 useful wetting agents include decanoyl-N-methylglucamide; n-decyl- $\beta$ -D-



glucopyranoside; n-decyl- $\beta$ -D-maltopyranoside; n-dodecyl- $\beta$ -D-glucopyranoside; n-dodecyl  $\beta$ -D-maltoside; heptanoyl-N-methylglucamide; n-heptyl- $\beta$ -D-glucopyranoside; n-heptyl- $\beta$ -D-thioglucoside; n-hexyl- $\beta$ -D-glucopyranoside; nonanoyl-N-methylglucamide; n-nonyl- $\beta$ -D-glucopyranoside; 5 octanoyl-N-methylglucamide; n-octyl- $\beta$ -D-glucopyranoside; and octyl- $\beta$ -D-thioglucopyranoside. Another preferred wetting agent is p-isononylphenoxypoly(glycidol), also known as Olin-10G or Surfactant 10-G (commercially available as 10G from Olin Chemicals). Two or more wetting agents can be used in combination.

10 (iv) Tonicity or Osmolality Agents

The porous drug matrices may include one or more tonicity agents, such as salts (e.g., as sodium chloride or potassium chloride) or sugars (such as mannitol, dextrose, sucrose, or trehalose) to adjust a hypotonic solution of a drug to isotonic so that the drug, when in solution, is physiologically compatible 15 with the cells of the body tissue of the patient. The type and amount of tonicity agent can be selected by one of skill in the art using known techniques.

(v) PEGylated Excipients

In one embodiment, the matrix further includes a pegylated excipient. Such pegylated excipients include, but are not limited to, pegylated 20 phospholipids, pegylated proteins, pegylated peptides, pegylated sugars, pegylated polysaccharides, pegylated block-co-polymers with one of the blocks being PEG, and pegylated hydrophobic compounds such as pegylated cholesterol. The pegylated excipient beneficially envelops or shields the drug from macrophage uptake, which prolongs its half-life or enhances bioavailability 25 of the drug.

Representative examples of pegylated phospholipids include 1,2-diacyl-*sn*-glycero-3-phosphoethanolamine-N-[Poly(ethylene glycol) 2000] ("PEG 2000 PE") and 1,2-diacyl-*sn*-glycero-3-phosphoethanolamine-N-[Poly(ethylene glycol) 5000] ("PEG 5000 PE"), where the acyl group is selected, for example, 30 from dimyristoyl, dipalmitoyl, distearoyl, dioleoyl, and 1-palmitoyl-2-oleoyl.

Other polyalkyleneoxides can be used in the place of the polyethylene glycol moiety.

## **II. Volatile Solvents**

The choice of solvent depends on the drug. In a preferred embodiment, the solvent is an organic solvent that is volatile, has a relatively low boiling point, or can be removed under vacuum, and which is acceptable for administration to humans in trace amounts. Representative solvents include acetic acid, acetaldehyde dimethyl acetal, acetone, acetonitrile, chloroform, chlorofluorocarbons, dichloromethane, dipropyl ether, diisopropyl ether, N,N-dimethylformamide (DMF), formamide, dimethyl sulfoxide (DMSO), dioxane, ethanol, ethyl acetate, ethyl formate, ethyl vinyl ether, methyl ethyl ketone (MEK), glycerol, heptane, hexane, isopropanol, methanol, isopropanol, butanol, triethylamine, nitromethane, octane, pentane, tetrahydrofuran (THF), toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethylene, water, xylene, and combinations thereof. In general, the drug is dissolved in the volatile solvent to form a drug solution having a concentration of between 0.01 and 80% weight to volume (w/v), more preferably between 0.025 and 30% (w/v).

When the drug is a water soluble drug, aqueous solvents or mixtures of aqueous and organic solvents, such as water-alcohol mixtures, can be used to dissolve the drug.

## **III. Pore Forming Agents**

Pore forming agents are volatile materials that are used during the process to create porosity in the resultant matrix. The pore forming agent can be a volatilizable solid or volatilizable liquid.

### **1. Liquid Pore Forming Agent**

The liquid pore forming agent must be immiscible with the drug solvent and volatilizable under processing conditions compatible with the drug. To effect pore formation, the pore forming agent first is emulsified with the drug solvent. Then, the emulsion is further processed to remove the drug solvent and the pore forming agent simultaneously or sequentially using evaporation,

vacuum drying, spray drying, fluid bed drying, lyophilization, or a combination of these techniques.

The selection of liquid pore forming agents will depend on the drug solvent. Representative liquid pore forming agents include water;

5 dichloromethane; alcohols such as ethanol, methanol, or isopropanol; acetone; ethyl acetate; ethyl formate; dimethylsulfoxide; acetonitrile; toluene; xylene; dimethylformamide; ethers such as THF, diethyl ether, or dioxane; triethylamine; formamide; acetic acid; methyl ethyl ketone; pyridine; hexane; pentane; furan; water; and cyclohexane.

10 The liquid pore forming agent is used in an amount that is between 1 and 50% (v/v), preferably between 5 and 25% (v/v), of the drug solvent emulsion.

## **2. Solid Pore Forming Agent**

The solid pore forming agent must be volatilizable under processing  
15 conditions which do not harm the drug compositions. The solid pore forming agent can be (i) dissolved in the drug solution, (ii) dissolved in a solvent which is not miscible with the drug solvent to form a solution which is then emulsified with the drug solution, or (iii) added as solid particulates to the drug solution. The solution, emulsion, or suspension of the pore forming agent in the drug  
20 solution then is further processed to remove the drug solvent, the pore forming agent, and, if appropriate, the solvent for the pore forming agent simultaneously or sequentially using evaporation, spray drying, fluid bed drying, lyophilization, vacuum drying, or a combination of these techniques.

In a preferred embodiment, the solid pore forming agent is a volatile salt,  
25 such as salts of volatile bases combined with volatile acids. Volatile salts are materials that can transform from a solid or liquid to a gaseous state using added heat and/or vacuum. Examples of volatile bases include ammonia, methylamine, ethylamine, dimethylamine, diethylamine, methylethylamine, trimethylamine, triethylamine, and pyridine. Examples of volatile acids include  
30 carbonic acid, hydrochloric acid, hydrobromic acid, hydroiodic acid, formic

acid, acetic acid, propionic acid, butyric acid, and benzoic acid. Preferred volatile salts include ammonium bicarbonate, ammonium acetate, ammonium chloride, ammonium benzoate and mixtures thereof.

- Other examples of solid pore forming agents include iodine, phenol, benzoic acid (as acid not as salt), and naphthalene.

The solid pore forming agent is used in an amount between 5 and 1000% (w/w), preferably between 10 and 600% (w/w), and more preferably between 10 and 100% (w/w), of the drug.

#### **IV. Method of Making the Porous Drug Matrix**

- The porous drug matrices preferably are made by (i) dissolving a drug, preferably one having low aqueous solubility, in a volatile solvent to form a drug solution, (ii) combining at least one pore forming agent with the drug solution to form an emulsion, suspension, or second solution, and (iii) removing the volatile solvent and pore forming agent from the emulsion, suspension, or second solution. In a preferred embodiment, spray drying, optionally followed by lyophilization or vacuum drying, is used to remove the solvents and the pore forming agent. The removal of the pore forming agent can be conducted simultaneously with or following removal of enough solvent to solidify the droplets. Production can be carried out using continuous, batch, or semi-continuous processes.

First, the selected drug is dissolved in an appropriate solvent. The concentration of the drug in the resulting drug solution typically is between about 0.01 and 80% (w/v), preferably between about 0.025 and 30% (w/v).

- Next, the drug solution is combined, typically under mixing conditions, with the pore forming agent or solution thereof. If a liquid pore forming agent is used, it is first emulsified with the drug solution to form droplets of pore forming agent dispersed throughout the drug solution. If a solid pore forming agent is used, it is dissolved either directly in the drug solution to form a solution of drug/pore forming agent, or it is first dissolved in a second solvent which is immiscible with the drug solvent to form a solution which subsequently

is emulsified with the drug solution to form droplets of the pore forming agent solution dispersed throughout the drug solution. A solid pore forming agent alternatively can be added directly to the drug solution as solid particulates, preferably between about 100 nm and 10  $\mu$ m in size, to form a suspension of pore forming agent in the drug solution. Subsequently, the solid pore forming agent particle size can be reduced by further processing the resulting suspension, for example, using homogenization or sonication techniques known in the art.

Then, the solution, emulsion, or suspension is further processed to remove the drug solvent and the pore forming agent simultaneously or sequentially, using evaporation, spray drying, fluid bed drying, lyophilization, vacuum drying, or a combination of these techniques. In a preferred embodiment, the solution, emulsion, or suspension is spray-dried. As used herein, "spray dry" means to atomize the solution, emulsion, or suspension to form a fine mist of droplets (of drug solution having solid or liquid pore forming agent dispersed throughout), which immediately enter a drying chamber (e.g., a vessel, tank, tubing, or coil) where they contact a drying gas. The solvent and pore forming agents evaporate from the droplets into the drying gas to solidify the droplets, simultaneously forming pores throughout the solid. The solid (typically in a powder, particulate form) then is separated from the drying gas and collected.

The temperature of the inlet and outlet ports of the drying chamber, as well as the flow rates of the feed solution, atomization gas, and drying gas, can be controlled to produce the desired products. In a particularly preferred embodiment, the spray drying methods described in U.S. Patent No. 5,853,698 to Straub et al., which is hereby incorporated by reference, are adapted to make the drug matrices described herein.

The drug present in the solids or powder produced may be in a crystalline or an amorphous state, or may be mixture of such states. The stated generally depends on how the droplets are dried and the excipients present.

### Emulsion Stabilization

In embodiments in which at least one pore forming agent is combined with the drug solution to form an emulsion, a surfactant or emulsifying agent can be added to enhance the stability of the emulsion. A variety of surfactants may be incorporated in this process, preferably to an amount between 0.1 and 5% by weight. Exemplary emulsifiers or surfactants which may be used include most physiologically acceptable emulsifiers, for instance egg lecithin or soya bean lecithin, or synthetic lecithins such as saturated synthetic lecithins, for example, dimyristoyl phosphatidyl choline, dipalmitoyl phosphatidyl choline or distearoyl phosphatidyl choline or unsaturated synthetic lecithins, such as dioleoyl phosphatidyl choline or dilinoleoyl phosphatidyl choline. Other hydrophobic or amphipathic compounds can be used in place of the phospholipid, for example, cholesterol. Emulsifiers also include surfactants such as free fatty acids, esters of fatty acids with polyoxyalkylene compounds like polyoxpropylene glycol and polyoxyethylene glycol; ethers of fatty alcohols with polyoxyalkylene glycols; esters of fatty acids with polyoxyalkylated sorbitan; soaps; glycerol-polyalkylene stearate; glycerol-polyoxyethylene ricinoleate; homo- and co-polymers of polyalkylene glycols; polyethoxylated soya-oil and castor oil as well as hydrogenated derivatives; ethers and esters of sucrose or other carbohydrates with fatty acids, fatty alcohols, these being optionally polyoxyalkylated; mono-, di- and tri-glycerides of saturated or unsaturated fatty acids, glycerides of soya-oil and sucrose.

Other emulsifiers include natural and synthetic forms of bile salts or bile acids, both conjugated with amino acids and unconjugated such as taurodeoxycholate and cholic acid.

### V. Porous Drug Matrix Applications

The porous drug matrices described herein are useful in formulations for administration to a patient in need of the drug. As used herein, "patient" refers to animals, including mammals, preferably humans. The formulations deliver a therapeutically or prophylactically effective amount of the drug to the patient.

The porous matrices, or formulations thereof, are suitable for administration of drug by a variety of routes, for example, parenteral, mucosal, oral, topical/transdermal administration, for local, regional, or systemic effect. Examples of parenteral routes include intravenous, intraarterial, intracardiac, intrathecal, intraosseous, intraarticular, intrasynovial, intracutaneous, subcutaneous, and intramuscular administration. Examples of mucosal routes include pulmonary (intrarespiratory), buccal, sublingual, intranasal, rectal, and vaginal administration. The porous matrices also can be formulated for intraocular, conjunctival, aural, urethral, intracranial, intralesional, and intratumoral administration.

In a preferred embodiment, the drug matrix is in the form of powder, which can be reconstituted with an aqueous medium, such as physiological saline, and administered parenterally, such as intramuscularly, subcutaneously, or intravenously. An advantage of the formulations described herein is that they can be used to convert drugs which must be infused (e.g., to avoid precipitation of the drug following bolus injection) to a bolus formulation, avoiding unacceptable precipitation of drug *in vivo* or for local delivery.

Alternatively, the matrix can be further processed using standard techniques into tablets or capsules for oral administration, into rectal suppositories, into a dry powder inhaler for pulmonary administration, or mixed/processed into a cream or ointment for topical administration. These standard techniques are described, for example, in Ansel, et al., "*Pharmaceutical Dosage Forms and Drug Delivery Systems*," 6<sup>th</sup> Ed., (Williams & Wilkins 1995), which is incorporated herein by reference.

The present invention will be further understood with reference to the following non-limiting examples.

#### Overview

Examples 1-10 demonstrate production of porous drug matrices using different pore forming agents, different drugs, and different solvents. Examples 1-8 use emulsion formulations to produce the matrices, whereas Examples 9 and

10 use solution formulations to produce the matrices.

Examples 11-13 describe the analyses which were used to characterize the porous drug matrices produced in Examples 1-10. These characteristics include density, drug integrity, and dissolution properties. Example 14

5 describes particle size analysis and surface area analysis of low water solubility drug particles incorporated into the porous drug matrices.

Examples 15-17 describe experiments demonstrating the increased internal surface area of porous drug matrices produced with pore forming agents. Examples 18-21 describe experiments demonstrating the advantage or  
10 need to include a wetting agent as a component of the porous drug matrices.

Example 22 describes an experiment demonstrating the administration of porous drug matrices as an intravenous bolus.

Examples 23 and 24 describe the production of porous drug matrices produced with pore forming agents and pegylated phospholipids.

## 15 Materials and Equipment

The following materials and equipment were used in the examples. PEG 3350, PEG 8000, polyvinylpyrrolidone K-15, nifedipine, naproxen, prednisone, SPAN<sup>TM</sup> 40, lecithin, TWEEN<sup>TM</sup> 80, PLURONIC<sup>TM</sup> F127, ammonium chloride, ammonium bicarbonate, and ammonium acetate were obtained from Spectrum  
20 Chemicals (Gardena, CA). Griseofulvin was obtained from Aldrich Chemicals (Milwaukee, WI). Taxol was obtained from Hauser (Boulder, CO). 1,2-Dimyristoyl-sn-Glycero-3-Phosphoethanolamine-N-[Poly(ethylene glycol)-5000] (PEG 5000 PE) and 1,2-Dimyristoyl-sn-Glycero-3-Phosphoethanolamine-N-[Poly(ethylene glycol)-2000] (PEG 2000 PE) were obtained from Avanti  
25 Polar Lipids Inc. (Alabaster, AL). Methylene chloride was obtained from EM Science (Gibbstown, NJ). All emulsions were produced using a Virtis IQ<sup>2</sup> homogenizer (Virtis, Gardiner, NY). Formulations were spray dried on a benchtop spray dryer using an air atomizing nozzle.



**Example 1: Production of a Porous Prednisone Matrix Using Ammonium Bicarbonate as a Pore Forming Agent with SPAN™ 40 and PEG 8000 as Wetting Agents**

5 5.46 g of PEG 8000, 0.545 g of prednisone, and 0.055 g of SPAN™ 40 were dissolved in 182 mL of methylene chloride. An aqueous solution was prepared by dissolving 3.27 g of ammonium bicarbonate in 18.2 mL of deionized (DI) water. The aqueous solution was added to the organic solution (phase ratio 1:10) and homogenized for 5 minutes at 16,000 RPM. The resulting emulsion was spray dried on a benchtop spray dryer using an air-atomizing  
10 nozzle and nitrogen as the drying gas. Spray drying process conditions were 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 36 °C outlet temperature.

**Example 2: Production of a Porous Prednisone Matrix Using Ammonium Bicarbonate as a Pore Forming Agent with PEG 8000, TWEEEN™ 80, Lecithin as Wetting Agents**

15 5.46 g of PEG 8000, 0.545 g of prednisone, 0.003 g of TWEEEN™ 80, and 0.003 g of lecithin were dissolved in 182 mL of methylene chloride. An aqueous solution was prepared as described in Example 1. The aqueous solution  
20 was added to the organic solution (phase ratio 1:10) and homogenized for 15 minutes as described in Example 1. The resulting emulsion was spray dried as described in Example 1 using process conditions of 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 35 °C outlet temperature.

**Example 3: Production of a Porous Prednisone Matrix Using Ammonium Acetate as a Pore Forming Agent, and PEG 8000, TWEEEN™ 80, and Lecithin as Wetting Agents**

25 A prednisone-loaded organic solution was prepared as described in Example 2. An aqueous solution was prepared by dissolving 3.27 g of  
30 ammonium acetate in 18.2 mL of DI water. The aqueous and organic solutions

were homogenized and spray dried as described in Example 2.

**Example 4: Production of a Porous Prednisone Matrix Using Ammonium Chloride as a Pore Forming Agent, and PEG 8000, TWEEN<sup>TM</sup> 80, and Lecithin as Wetting Agents**

A prednisone-loaded organic solution was prepared as described in Example 2. An aqueous solution was prepared by dissolving 3.27 g of ammonium chloride in 18.2 mL of DI water. The aqueous and organic solutions were homogenized as described in Example 1. The resulting emulsion was spray dried as described in Example 2.

**Example 5: Production of a Porous Griseofulvin Matrix Using Ammonium Bicarbonate as a Pore Forming Agent, and PEG 3350, TWEEN<sup>TM</sup> 80, and Lecithin as Wetting Agents**

9.09 g of PEG 3350, 4.55 g of griseofulvin, 0.01 g of TWEEN<sup>TM</sup> 80, and 0.01 g of lecithin were dissolved in 182 mL of methylene chloride. An aqueous solution was prepared by dissolving 3.27 g of ammonium bicarbonate and 1.09 g of PEG 3350 in 18.2 mL of DI water. The aqueous and organic solutions were homogenized as described in Example 1. The resulting emulsion was spray dried as described in Example 1 using process conditions of 20 ml/min solution flow rate, 80 kg/hr drying gas rate, and 12 °C outlet temperature.

**Example 6: Production of a Porous Nifedipine Matrix Using Ammonium Bicarbonate as a Pore Forming Agent, and PEG 3350 and Lecithin as Wetting Agents**

9.09 g of PEG 3350, 2.27 g of nifedipine, and 0.009 g of lecithin were dissolved in 182 mL of methylene chloride. An aqueous solution was prepared by dissolving 3.27 g of ammonium bicarbonate in 18.2 mL of DI water. The aqueous and organic solutions were homogenized in described in Example 1. The resulting emulsion was spray dried as described in Example 1 using process

conditions of 20 ml/min solution flow rate, 60 kg/hr drying gas rate, and 20 °C outlet temperature.

**Example 7: Production of a Porous Naproxen Matrix Using Ammonium Chloride as a Pore Forming Agent, and PEG 3350 and Lecithin as Wetting Agents**

A naproxen-loaded organic solution was prepared by dissolving 10.91 g of PEG 3350, 2.73 g of naproxen, and 0.109 g of lecithin in 182 mL of methylene chloride. An aqueous solution was prepared as described in Example 4. The aqueous and organic solutions were homogenized as described in Example 1, and the resulting emulsion was spray dried using process conditions of 20 ml/min solution flow rate, 100 kg/hr drying gas rate, and 20 °C outlet temperature.

**Example 8: Production of a Porous Paclitaxel Matrix Using Ammonium Bicarbonate as a Pore Forming Agent, and PEG 3350 and Lecithin as Wetting Agents**

A paclitaxel-loaded organic solution was prepared by dissolving 3.0 g of paclitaxel, 15.0 g of PEG 3350, and 15.7 mg of lecithin in 100 mL of methylene chloride. An aqueous solution composed of 1.8 g of ammonium bicarbonate and 0.6 g of PEG 3350 in 10 mL of DI water was added to the organic solution (phase ratio 1:10). The mixture was homogenized for 5 minutes at 16,000 RPM. The resulting emulsion was spray dried using process conditions of 10 mL/min solution flow rate, 60 kg/hr drying gas rate, and 25 °C outlet temperature.

**Example 9: Production of a Porous Nifedipine Matrix Using Ammonium Bicarbonate as a Pore Forming Agent, PEG 3350 and TWEEN™ 80 as Wetting Agents, Polyvinylpyrrolidone as a Bulking Agent, and Ethanol as a Solvent**

A nifedipine-loaded organic solution was prepared by dissolving 0.76 g

of nifedipine, 0.28 g of PEG 3350, and 2.72 g of polyvinylpyrrolidone K-15 in 170 mL of ethanol. An aqueous solution composed of 1.62 g of ammonium bicarbonate and 3 mg of TWEEN™ 80 in 30 mL of DI water was added to the ethanol solution and mixed. The resulting solution was spray dried using  
5 process conditions of 20 mL/min solution flow rate, 100 kg/hr drying gas rate, and 36 °C outlet temperature.

**Example 10: Production of a Porous Nifedipine Matrix Using Ammonium Bicarbonate as a Pore Forming Agent, PEG 3350 and  
10 PLURONIC™ F127 as Wetting Agents, Polyvinylpyrrolidone as a Bulking Agent, and Ethanol as a Solvent**

A nifedipine-loaded organic solution was prepared by dissolving 0.76 g of nifedipine, 0.28 g of PEG 3350, and 2.72 g of polyvinylpyrrolidone K-15 in 170 mL of ethanol. An aqueous solution composed of 1.62 g of ammonium  
15 bicarbonate and 3 mg of PLURONIC™ F127 in 30 mL of DI water was added to the ethanol solution and mixed. The resulting solution was spray dried using process conditions of 20 mL/min solution flow rate, 100 kg/hr drying gas rate, and 36 °C outlet temperature.

**20 Example 11: In Vitro Dissolution of Porous Drug Matrices**

The *in vitro* dissolution rates of the powders produced in Examples 1-10 were compared to the dissolution rates of the bulk drug of interest.

Analytical Method

All dissolution studies were conducted in PBS (phosphate buffered  
25 saline) at room temperature in a glass beaker using overhead mixing. The mixer used was an IKARW16 Basic Mixer with a R1342 impeller shaft running at stirring rate 5. Samples were removed via pipet, filtered through 0.22 micron CA syringe filter, and then analyzed. UV-vis spectroscopy was conducted on an Hewlett Packard Model 8453. Dissolution curves are presented as percent of  
30 complete dissolution.

For griseofulvin, PBS (600 mL) was added to an appropriate amount of material being tested to contain 2.4 mg of griseofulvin. UV analysis was performed at 291 nm.

For naproxen, PBS (100 mL) was added to an appropriate amount of material being tested to contain 100 mg of naproxen. All vessels containing naproxen as a solid or as a solution were protected from light. UV analysis was performed at 332 nm.

For nifedipine, PBS (600 mL) was added to an appropriate amount of material being tested to contain 2.4 mg of nifedipine. All vessels containing nifedipine as a solid or in solution were protected from light. UV analysis was performed at 237 nm.

For prednisone, PBS (250 mL) was added to an appropriate amount of material being tested to contain 5 mg of prednisone. UV analysis was performed at 244 nm.

For paclitaxel, studies were conducted in PBS containing 0.08% TWEEN<sup>TM</sup> 80 (T80/PBS). T80/PBS (10 mL) was added to an appropriate amount of material being tested to contain 5 mg of paclitaxel in a 15 mL polypropylene conical tube, and the suspension was vortexed for 3-4 minutes. The suspension (0.25 mL) was then added to 250 mL of T80/PBS in a 600 mL glass beaker for dissolution analysis. HPLC analysis was performed directly on the filtered aqueous solutions using the paclitaxel HPLC method described in Example 13.

### Results

The *in vitro* dissolution rates of the porous drug matrices produced in examples 1-10 are provided in Figures 1-6. The *in vitro* dissolution of the porous drug matrices are compared to the bulk drug of interest. In all cases, the time for 80% dissolution of the porous drug matrices is 4-50 times shorter than the time for 80% of the bulk drug to dissolve. The rate of dissolution which is approximated as the slope of the curve is 10 to 1400 times greater for the porous drug matrices of Examples 1-10 as compared to the specific bulk drug of

interest.

### Example 12: Density of Porous Drug Matrices

The densities of the dry powder produced in Examples 1-7 are summarized in Table 1. Density was measured using Transaxial Pressure (“TAP”) with a Micromeritics GeoPyc 1360 using a consolidation force of 8 Newtons. The matrices are less dense than the starting bulk drug in all cases, indicating that the porous drug matrices are more porous than the commercially available bulk drug.

10 **Table 1: Particle Density Analysis**

Material	Density (g/mL)
Prednisone Bulk	0.68
Example 1	0.48
Example 2	0.55
Example 3	0.51
Example 4	0.49
Griseofulvin Bulk	0.80
Example 5	0.55
Nifedipine Bulk	1.01
Example 6	0.56
Naproxen Bulk	0.69
Example 7	0.58

### Example 13: Integrity of the Drug in Porous Drug Matrices

#### Analytical Method

Drug integrity post processing was assessed by High Pressure Liquid Chromatography (“HPLC”) (Hewlett Packard Series 1100 HPLC). USP chromatography conditions were used for prednisone, naproxen, nifedipine, and griseofulvin. Vessels and vials containing naproxen or nifedipine solutions were protected from light. For paclitaxel, the chromatographic conditions included a Nucleosil column (5 :m, C18, 100A, 250 x 4.6 mm), a mobile phase of 2 mM H<sub>3</sub>PO<sub>4</sub>/Acetonitrile (2:3) at a flow rate of 1.5 mL/min, UV detection at 227 nm,

and a run time of 25 min.

### Results

The integrities of the drugs following the processing in Examples 1-9 are shown in Table 2 as purities. The process of forming the drug into porous  
5 matrices does not appear to alter the purity of the drug.

**Table 2: Drug Integrity Analysis**

Material	Purity (%)
Prednisone Powder	100
Example 1	99.8
Example 2	99.8
Example 3	99.8
Example 4	99.8
Griseofulvin Bulk	95.7
Example 5	95.7
Nifedipine Bulk	100
Example 6	100
Example 9	100
Example 10	100
Naproxen Bulk	100
Example 7	100
Paclitaxel Bulk	100
Example 8	100

### **Example 14: Particle Size Analysis and Surface Area Analysis**

#### **10 of Drug Particles in Wetted Porous Drug Matrices**

#### Analytical Methods

Particle size analysis was performed using the Coulter Multisizer II with a 50 micron aperture using siphon mode. Electrolyte was pre-saturated with the drug of interest, and filtered through a 0.22 micron filter prior to addition of lots  
15 for analysis to ensure that no portion of the drug within the lot would dissolve during the analysis.

## Results

The mean particle size and total surface area of the drug particles generated when the porous drug matrices produced in Examples 1-7 were reconstituted in aqueous media are summarized in Table 3.

5

**Table 3: Particle Size and Surface Area Analysis**

Material	Size (microns)	Surface Area (m <sup>2</sup> /mL of microparticles)
Prednisone Powder	2.07	1.43
Example 1	1.58	1.66
Example 2	1.39	2.53
Example 3	1.39	3.02
Example 4	1.24	3.36
Griseofulvin Bulk	2.42	0.88
Example 5	2.16	1.28
Nifedipine Bulk	2.64	0.57
Example 6	1.78	1.98
Naproxen Bulk	2.89	0.66
Example 7	1.34	2.79

In all cases, the particle size of the drug particles which resulted from wetting of the porous drug matrices was reduced relative to the starting bulk material by 10  
10 to 54%, and the total surface area of the particles was increased relative to the starting bulk drug by approximately 16-320%.

### **Example 15: Nifedipine Drug Matrices Containing a Wetting Agent Produced With and Without a Pore Forming Agent**

15 A nifedipine/PEG solution was prepared by dissolving 2.0 g of nifedipine, 8.0 g of PEG 3350, and 8 mg of lecithin in 200 mL of methylene chloride (Example 15A). A second identical nifedipine-loaded organic solution was prepared. An aqueous solution composed of 1.8 g of ammonium bicarbonate in 20 mL of DI water was added to the first nifedipine organic



solution (phase ratio 1:10). The mixture was homogenized for 5 minutes at 16,000 RPM. The nifedipine solution (Example 15A) and the nifedipine emulsion (Example 15B) were separately spray dried using process conditions of 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 21 °C outlet temperature.

**Example 16: Griseofulvin Drug Matrices Containing a Wetting Agent Produced With and Without a Pore Forming Agent**

A griseofulvin/PEG solution was prepared by dissolving 5.0 g of griseofulvin, 11.2 g of PEG 3350, 11 mg of TWEEN<sup>TM</sup> 80, and 11 mg of lecithin in 200 mL of methylene chloride (Example 16A). A second identical griseofulvin-loaded organic solution was prepared. An aqueous solution composed of 1.8 g of ammonium bicarbonate in 20 mL of DI water was added to the first organic solution (phase ratio 1:10). The mixture was homogenized for 5 minutes at 16,000 RPM. The griseofulvin solution (Example 16A) and griseofulvin emulsion (Example 16B) were spray dried on a benchtop spray dryer using process conditions of 20 mL/min solution flow rate, 80 kg/hr drying gas rate, and 13 °C outlet temperature.

**Example 17: Internal Surface Area of Porous Drug Matrices Containing a Wetting Agent and Produced With and Without a Pore Forming Agent**

The internal surface areas of the drug matrices produced in Examples 15 and 16 were assessed by Krypton BET. BET specific surface area analysis was performed using multi-point surface area analysis with krypton as the gas. Samples were outgassed to 20 micron vacuum at 20 °C prior to analysis.

The results, shown in Table 4, illustrate that the use of the pore forming agent led to an increase of between 2.3 and 3.5 fold in the internal surface area of the resultant drug matrix.

**Table 4: Internal Surface Area of Drug Matrices**

Matrix (Example No.)	Surface Area (m <sup>2</sup> /g matrix)
Nifedipine with wetting agent (15A)	0.40
Nifedipine with wetting agent and Ammonium Bicarbonate (15B)	1.4
Griseofulvin with wetting agent (16A)	0.41
Griseofulvin with wetting agent and Ammonium Bicarbonate (16B)	0.95

**Example 18: Nifedipine Drug Matrix Produced Without a Pore Forming Agent or Wetting Agent**

- 5           A 5% nifedipine solution was prepared by dissolving 10.0 g of nifedipine in 200 mL of methylene chloride. The solution was spray dried on a benchtop spray dryer using the following conditions: 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 22°C outlet temperature.

10   **Example 19: Griseofulvin Drug Matrix Produced Without a Pore Forming Agent or Wetting Agent**

- An 8.1% griseofulvin solution was prepared by dissolving 16.2 g of griseofulvin in 200 mL of methylene chloride. The solution was spray dried on a benchtop spray dryer using process conditions of 20 mL/min solution flow rate, 80 kg/hr drying gas rate, and 13 °C outlet temperature.
- 15

**Example 20: *In Vitro* Dissolution of Nifedipine Drug Matrices Produced With / Without Pore Forming Agent and Wetting Agent**

- The *in vitro* dissolution rates of the nifedipine matrices produced in Examples 15 and 18 are shown in Figure 6. The *in vitro* dissolution of the drug matrices produced with either wetting agent or wetting agent and pore forming agent have increased dissolution rates as compared to the drug matrix produced with the drug alone. The matrix produced with both the wetting agent and the pore forming agent has the greatest dissolution rate.
- 20

25

**Example 21: *In Vitro* Dissolution of Griseofulvin Drug Matrices Produced With / Without Pore Forming Agent and Wetting Agent**

The *in vitro* dissolution rates of the griseofulvin matrices produced in examples 16 and 19 are provided in Figure 7. The *in vitro* dissolution of the drug matrices produced with either wetting agent or wetting agent and pore forming agent have increased dissolution rates as compared to the drug matrix produced with the drug alone. The matrix produced with both the wetting agent and the pore forming agent has the greatest dissolution rate.

**Example 22: Administration of Porous Drug Matrices as an Intravenous Bolus to Dogs**

A nifedipine-loaded organic solution was prepared by dissolving 9.09 g of PEG 3350, 2.27 g of nifedipine, and 0.009 g of lecithin in 182 mL of methylene chloride. An aqueous solution was prepared by dissolving 3.27 g of ammonium bicarbonate and 0.91 g of PEG 3350 in 18.2 mL of deionized water at room temperature. The aqueous and organic solutions were homogenized as described in Example 1, and the resulting emulsion was spray dried using process conditions of 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 20 °C outlet temperature.

A suspension of the porous nifedipine drug matrix was prepared in 5% dextrose solution at a concentration of 2.5 mg/mL. The suspension (2 mL) was administered as a bolus to four beagle dogs, which weighed 8-10 kg. Blood samples were taken at time-points ranging from 1 minute to 24 hours. The samples were processed into plasma, were stored frozen, and were protected from light until analysis via liquid chromatography-mass spectrometry.

All animals tolerated the suspension administered as a bolus. The average plasma levels of the intravenously administered suspension is shown in Figure 8.

**Example 23: Production of a Porous Nifedipine Matrix Using a Pegylated Phospholipid, 1, 2-Dimyristoyl-sn-Glycero-3-Phosphoethanolamine-N-[Poly(ethylene glycol)-5000]**

A nifedipine-loaded organic solution was prepared by dissolving 2.0 g of nifedipine, 30.0 g of PEG 3350, 4 mg of lecithin, and 4 mg of 1, 2-Dimyristoyl-sn-Glycero-3-Phosphoethanolamine-N-[Poly(ethylene glycol)-5000] (PEG 5000 PE) in 202 mL of methylene chloride. An aqueous solution of 1.8 g of ammonium bicarbonate in 20 mL of DI water was added to the organic solution (phase ratio 1:10). The mixture was homogenized for 5 minutes at 16,000 RPM. The resulting emulsion was spray dried using process conditions of 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 21 °C outlet temperature.

**Example 24: Production of a Porous Nifedipine Matrix Using a Pegylated Phospholipid, 1, 2-Dimyristoyl-sn-Glycero-3-Phosphoethanolamine-N-[Poly(ethylene glycol)-2000]**

A nifedipine-loaded organic solution was prepared by dissolving 2.0 g of nifedipine, 30.0 g of PEG 3350, 4 mg of lecithin, and 4 mg of 1, 2-Dimyristoyl-sn-Glycero-3-Phosphoethanolamine-N-[Poly(ethylene glycol)-2000] (PEG 2000 PE) in 202 mL of methylene chloride. An aqueous solution composed of 1.8 g of ammonium bicarbonate in 20 ml of DI water was added to the organic solution (phase ratio 1:10). The mixture was homogenized for 5 minutes at 16,000 RPM. The resulting emulsion was spray dried using process conditions of 20 mL/min solution flow rate, 60 kg/hr drying gas rate, and 21 °C outlet temperature.

Modifications and variations of the present invention will be obvious to those of skill in the art from the foregoing detailed description. Such modifications and variations are intended to come within the scope of the following claims.

We claim:

1. A pharmaceutical composition comprising a porous matrix formed of a wetting agent and microparticles of a drug,

wherein the microparticles have a mean diameter between about 0.1 and 5  $\mu\text{m}$  and a total surface area greater than about 0.5  $\text{m}^2/\text{mL}$ , and

wherein the dry porous matrix is in a dry powder form having a TAP density less than or equal to 1.0  $\text{g/mL}$  and/or having a total surface area of greater than or equal to 0.2  $\text{m}^2/\text{g}$ .

2. The composition of claim 1 wherein the drug is a low aqueous solubility drug.

3. The composition of claim 1 wherein the microparticles are made by a process comprising

(a) dissolving a drug in a volatile solvent to form a drug solution,

(b) combining at least one pore forming agent with the drug solution to form an emulsion, suspension, or second solution, and

(c) removing the volatile solvent and pore forming agent from the emulsion, suspension, or second solution to yield the porous drug matrix.

4. The composition of claim 3 wherein the drug has low aqueous solubility.

5. The composition of claim 3 wherein the pore forming agent is a volatile salt.

6. The composition of claim 1 wherein the drug is a low aqueous solubility drug, wherein the matrix upon contact with an aqueous medium yields microparticles having a mean diameter between about 0.1 and 5  $\mu\text{m}$  and a total surface area greater than about 0.5  $\text{m}^2/\text{mL}$ , and

wherein the dry porous matrix is in a dry powder form having a TAP density less than or equal to 1.0  $\text{g/mL}$  and/or having a total surface area of greater than or equal to 0.2  $\text{m}^2/\text{g}$ .

7. The composition of claim 6 wherein the drug is selected from the

group consisting of albuterol, adapalene, doxazosin mesylate, mometasone furoate, ursodiol, amphotericin, enalapril maleate, felodipine, nefazodone hydrochloride, valrubicin, albendazole, estrogens conjugated, medroxyprogesterone acetate, nicardipine hydrochloride, zolpidem tartrate, amlodipine besylate, ethinyl estradiol, omeprazole, rubitecan, amlodipine besylate/ benazepril hydrochloride, etodolac, paroxetine hydrochloride, paclitaxel, atovaquone, felodipine, podofilox, paricalcitol, betamethasone dipropionate, fentanyl, pramipexole dihydrochloride, Vitamin D<sub>3</sub> and related analogues,, finasteride, quetiapine fumarate, alprostadil candesartan, cilexetil, fluconazole, ritonavir, busulfan, carbamazepine, flumazenil, risperidone, carbamazepine, carbidopa/ levodopa, ganciclovir, saquinavir, amprenavir, carboplatin, glyburide, sertraline hydrochloride, rofecoxib carvedilol, halobetasolpropionate, sildenafil citrate, celecoxib, chlorthalidone, imiquimod, simvastatin, citalopram, ciprofloxacin, irinotecan hydrochloride, sparfloxacin, efavirenz, cisapride monohydrate, lansoprazole, tamsulosin hydrochloride, mofafinil, azithromycin, clarithromycin, letrozole, terbinafine hydrochloride, rosiglitazone maleate, diclofenac sodium, lomefloxacin hydrochloride, tirofiban hydrochloride, telmisartan, diazepam, loratadine, toremifene citrate, thalidomide, dinoprostone, mefloquine hydrochloride, trandolapril, docetaxel, mitoxantrone hydrochloride, tretinoin, etodolac, triamcinolone acetate, estradiol, ursodiol, nelfinavir mesylate, indinavir, beclomethasone dipropionate, oxaprozin, flutamide, famotidine, nifedipine, prednisone, cefuroxime, lorazepam, digoxin, lovastatin, griseofulvin, naproxen, ibuprofen, isotretinoin, tamoxifen citrate, nimodipine, amiodarone, and alprazolam.

8. The composition of claim 1 wherein the drug is water soluble.

9. The composition of claim 8 wherein the drug is selected from the group consisting of ceftriaxone, ketoconazole, ceftazidime, oxaprozin, albuterol, valacyclovir, urofollitropin, famciclovir, flutamide, enalapril, mefformin, itraconazole, buspirone, gabapentin, fosinopril, tramadol, acarbose, lorazepam, follitropin, glipizide, omeprazole, fluoxetine, lisinopril, levofloxacin, zafirlukast,

interferon, growth hormone, interleukin, erythropoietin, granulocyte stimulating factor, nizatidine, bupropion, perindopril, erbumine, adenosine, alendronate, alprostadil, benazepril, betaxolol, bleomycin sulfate, dexfenfluramine, diltiazem, fentanyl, flecainid, gemcitabine, glatiramer acetate, granisetron, lamivudine, mangafodipir trisodium, mesalamine, metoprolol fumarate, metronidazole, miglitol, moexipril, monteleukast, octreotide acetate, olopatadine, paricalcitol, somatropin, sumatriptan succinate, tacrine, verapamil, nabumetone, trovafloxacin, dolasetron, zidovudine, finasteride, tobramycin, isradipine, tolcapone, enoxaparin, fluconazole, lansoprazole, terbinafine, pamidronate, didanosine, diclofenac, cisapride, venlafaxine, troglitazone, fluvastatin, losartan, imiglucerase, donepezil, olanzapine, valsartan, fexofenadine, calcitonin, and ipratropium

10. The composition of claim 1 wherein the matrix further comprise an excipient selected from the group consisting of hydrophilic polymers, sugars, tonicity agents, pegylated excipients, and combinations thereof.

11. The composition of claim 1 wherein the mean diameter of the microparticles is between about 1 and 5  $\mu\text{m}$ .

12. The composition of claim 1 wherein the microparticles are suspended in an aqueous solution suitable for parenteral administration.

13. The composition of claim 1 wherein the matrix is processed into tablets or capsules suitable for oral administration.

14. The composition of claim 1 wherein the matrix is formed into suppositories suitable for vaginal or rectal administration.

15. The composition of claim 1 wherein the matrix is in a dry powder form suitable for pulmonary administration.

16. A method for making a porous matrix of drug comprising

(a) dissolving a drug in a volatile solvent to form a drug solution,

(b) combining at least one pore forming agent with the drug solution to form an emulsion, suspension, or second solution, and

(c) removing the volatile solvent and pore forming agent from the

emulsion, suspension, or second solution to yield the porous matrix of drug.

17. The method of claim 16 wherein the drug has low aqueous solubility.

18. The method of claim 16 further comprising incorporating at least one wetting agent into the emulsion, suspension, or second solution.

19. The method of claim 16 wherein step (c) is conducted using a process selected from spray drying, evaporation, fluid bed drying, lyophilization, vacuum drying, or a combination thereof.

20. The method of claim 16 wherein the drug solution or pore forming agent further comprises excipients selected from the group consisting of hydrophilic excipients, pegylated excipients, and tonicity agents.

21. The method of claim 16 wherein the pore forming agent is a volatile salt.

22. The method of claim 21 wherein the volatile salt is selected from the group consisting of ammonium bicarbonate, ammonium acetate, ammonium chloride, ammonium benzoate, and mixtures thereof.

23. A method of delivering a drug to a patient in need thereof, comprising

administering a therapeutically or prophylactically effective amount of the drug in a formulation comprising a porous matrix formed of a wetting agent and microparticles of the drug, wherein the microparticles have a mean diameter between about 0.1 and 5  $\mu\text{m}$  and a total surface area greater than about 0.5  $\text{m}^2/\text{mL}$ , and wherein the dry porous matrix is in a dry powder form having a TAP density less than or equal to 1.0  $\text{g/mL}$  and/or having a total surface area of greater than or equal to 0.2  $\text{m}^2/\text{g}$ .

24. The method of claim 23 wherein the formulation is suitable for administration by a route selected from the group consisting of parenteral, mucosal, oral, and topical administration.

25. The method of claim 24 wherein the parenteral route is selected from the group consisting of intravenous, intraarterial, intracardiac, intrathecal,



intraosseous, intraarticular, intrasynovial, intracutaneous, subcutaneous, and intramuscular administration.

26. The method of claim 24 wherein the mucosal route is selected from the group consisting of pulmonary, buccal, sublingual, intranasal, rectal, and vaginal administration.

27. The method of claim 23 wherein the formulation is suitable for intraocular or conjunctival administration.

28. The method of claim 23 wherein the formulation is suitable for intracranial, intralesional, or intratumoral administration.

29. The method of claim 23 wherein the formulation is in an aqueous solution suitable for parenteral administration.

30. The method of claim 23 wherein the formulation is in a tablet or capsule suitable for oral administration.

31. The method of claim 23 wherein the formulation is in a suppository suitable for vaginal or rectal administration.

32. The method of claim 23 wherein the formulation is a dry powder suitable for pulmonary administration.

## POROUS DRUG MATRICES AND METHODS OF MANUFACTURE THEREOF

### Abstract of the Disclosure

5           Drugs, especially low aqueous solubility drugs, are provided in a porous matrix form, preferably microparticles, which enhances dissolution of the drug in aqueous media. The drug matrices preferably are made using a process that includes (i) dissolving a drug, preferably a drug having low aqueous solubility, in a volatile solvent to form a drug solution, (ii) combining at least one pore  
10   forming agent with the drug solution to form an emulsion, suspension, or second solution, and (iii) removing the volatile solvent and pore forming agent from the emulsion, suspension, or second solution to yield the porous matrix of drug. The pore forming agent can be either a volatile liquid that is immiscible with the drug solvent or a volatile solid compound, preferably a volatile salt. In a  
15   preferred embodiment, spray drying is used to remove the solvents and the pore forming agent. The resulting porous matrix has a faster rate of dissolution following administration to a patient, as compared to non-porous matrix forms of the drug. In a preferred embodiment, microparticles of the porous drug matrix are reconstituted with an aqueous medium and administered parenterally,  
20   or processed using standard techniques into tablets or capsules for oral administration.

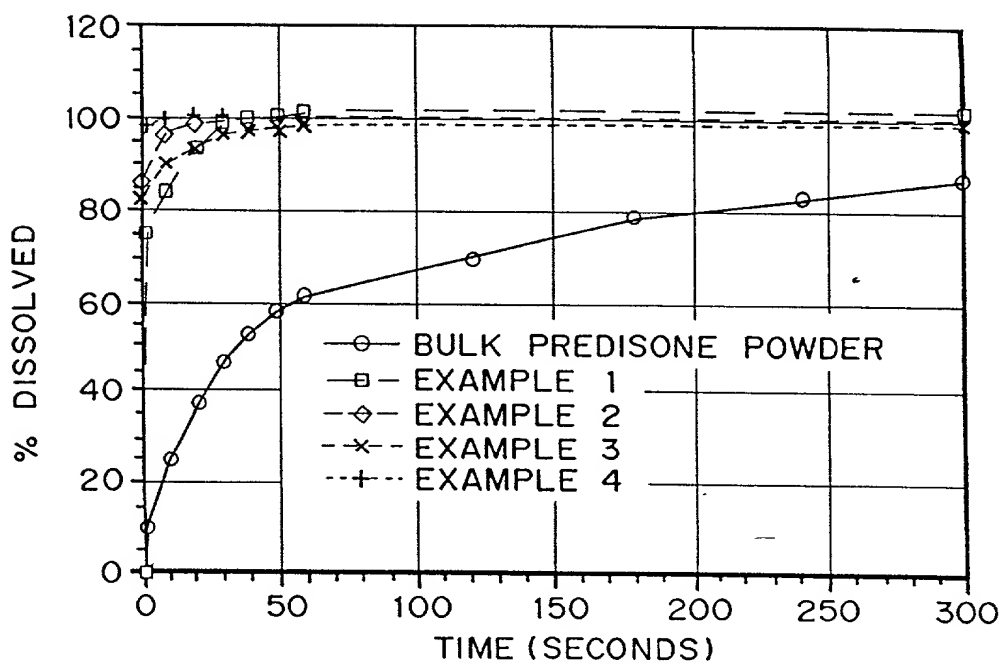


FIG. 1

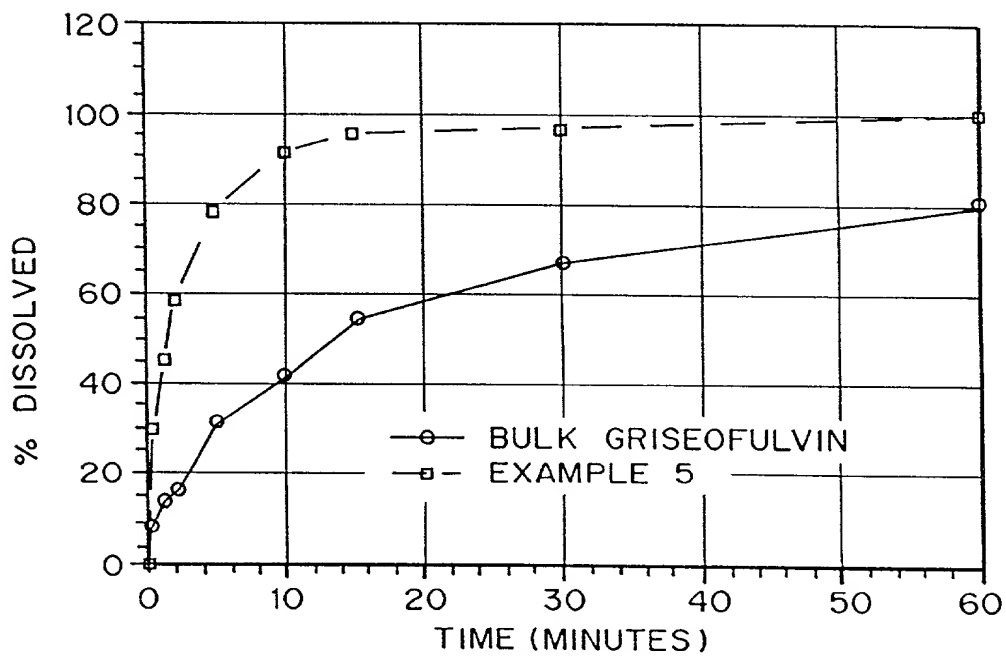


FIG. 2

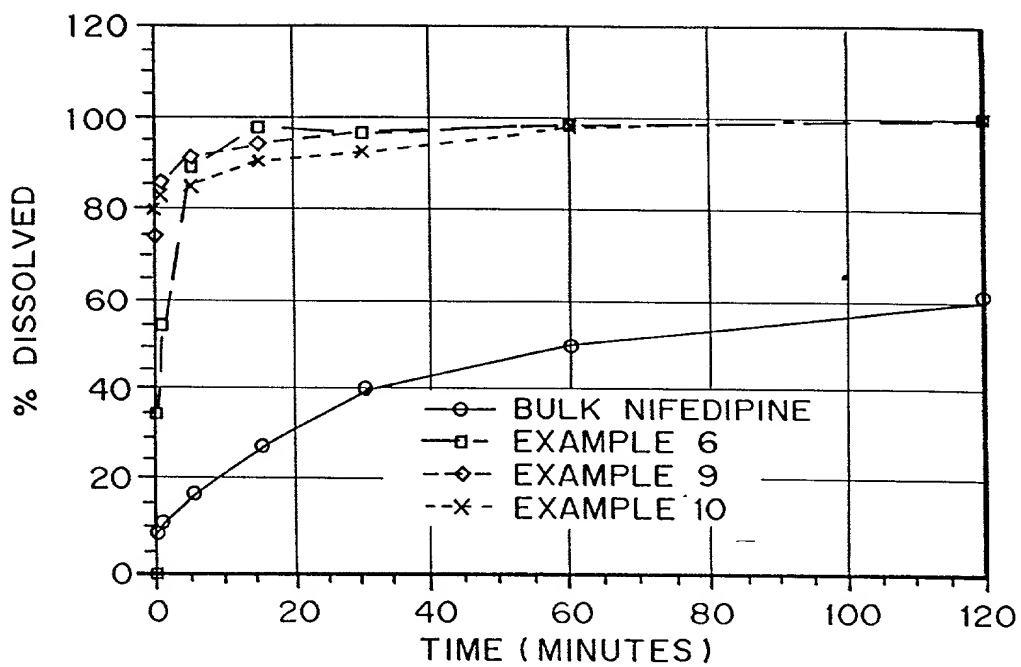


FIG. 3

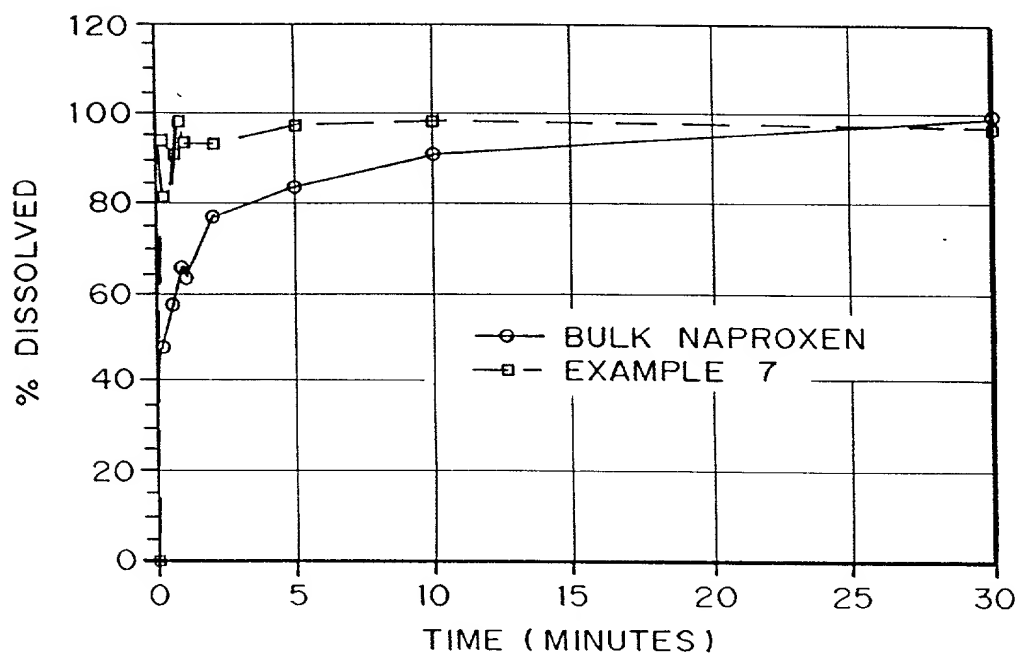
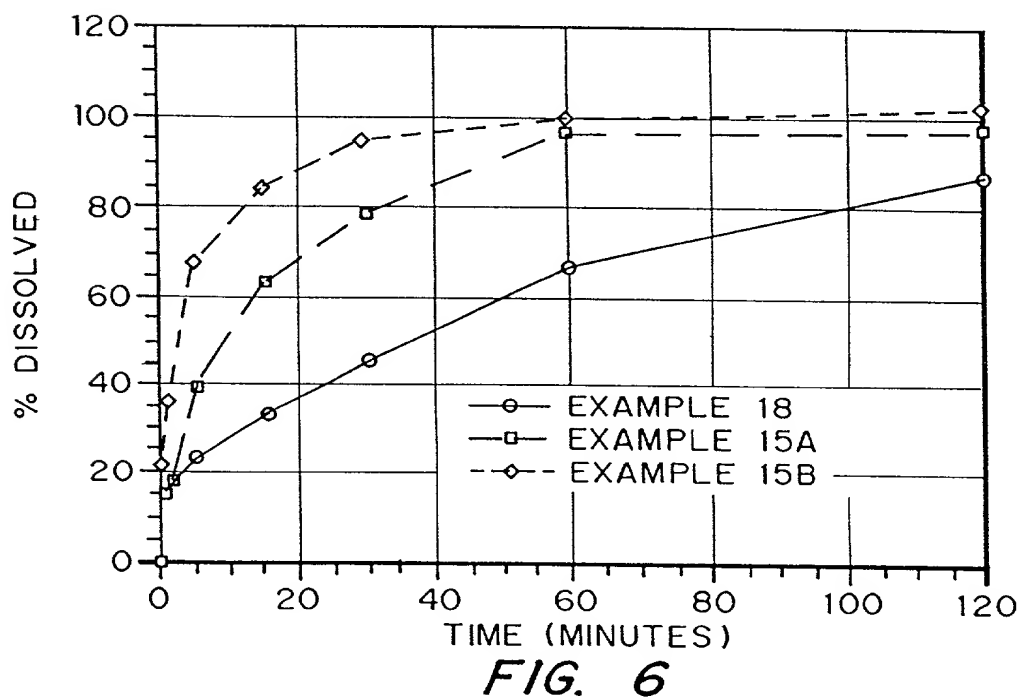
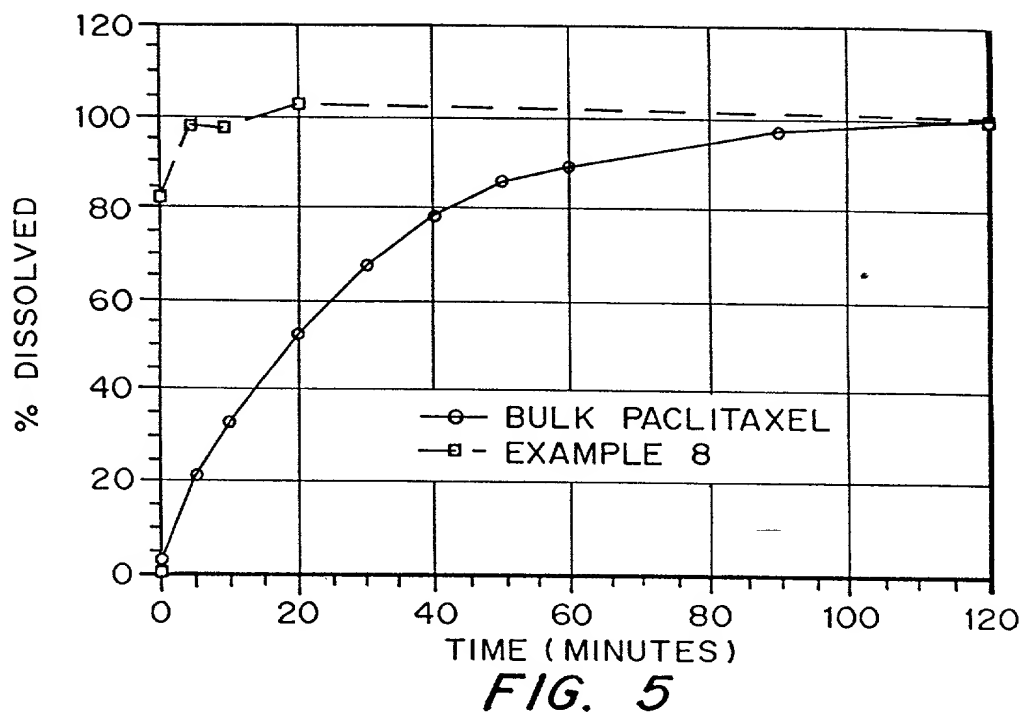


FIG. 4



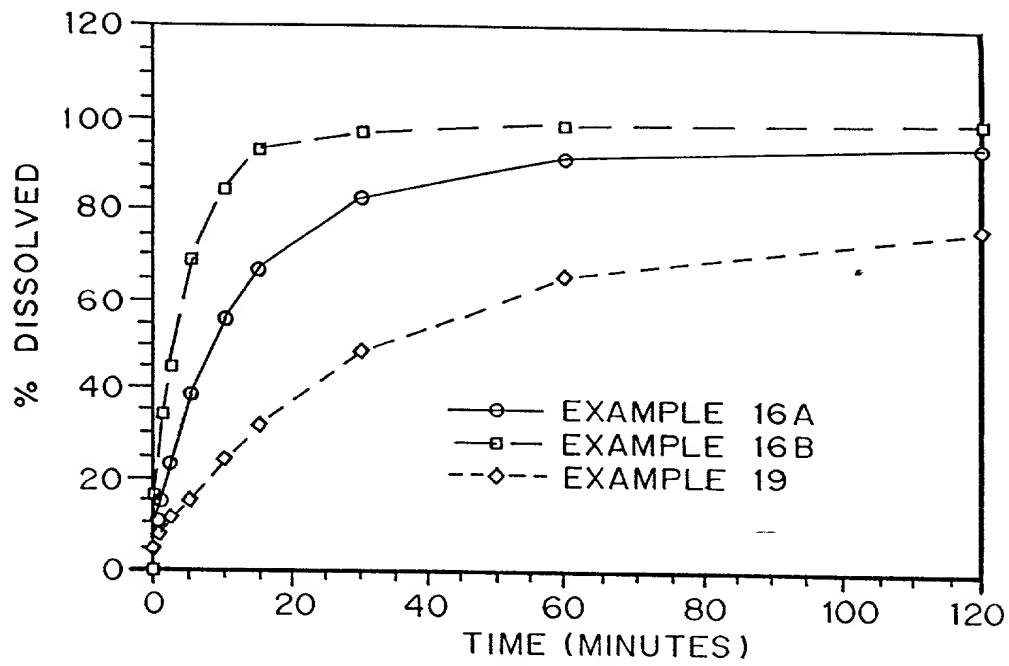


FIG. 7

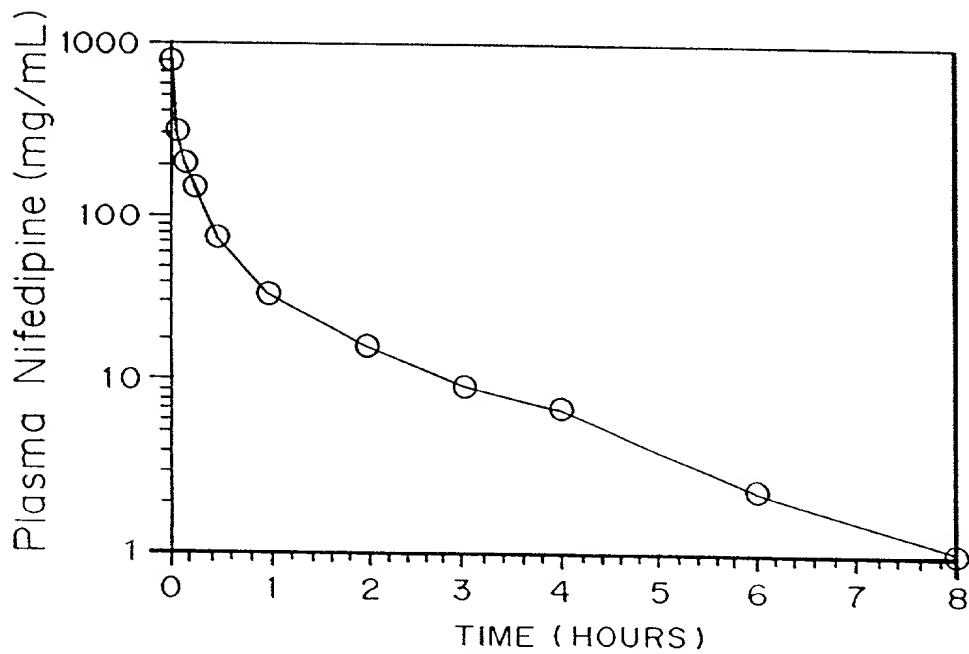


FIG. 8

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**DECLARATION FOR UTILITY OR  
DESIGN  
PATENT APPLICATION  
(37 CFR 1.63)**

☐ Declaration Submitted with Initial Filing OR ☒ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number ACU 109

First Named Inventor Julie Straub

**COMPLETE IF KNOWN**

Application Number 09 / 433,486

Filing Date November 4, 1999

Group Art Unit

Examiner Name

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**POROUS DRUG MATRICES AND METHODS  
OF MANUFACTURE THEREOF**

the specification of which  
☐ is attached hereto  
OR

☒ was filed on (MM/DD/YYYY) 11/04/1999 as United States Application Number or PCT International

Application Number 09/433,486 and was amended on (MM/DD/YYYY) (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
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			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	<input type="checkbox"/> Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.
60/136,323 60/158,659	May 27, 1999 October 8, 1999	

[Page 1 of 2]

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## DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

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As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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OR

☒ Registered practitioner(s) name/registration number listed below

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Name	Registration Number	Name	Registration Number
Patrea L. Pabst	31,284		
Robert A. Hodges	41,074		
Kevin W. King	42,737		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

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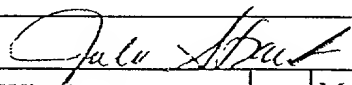
OR ☒ Correspondence address below

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor:

☐ A petition has been filed for this unsigned inventor

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Julie		Straub					
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Post Office Address	100 Cambridge Street						
Post Office Address							
City	Winchester	State	MA	ZIP	01890	Country	USA

☒ Additional inventors are being named on the 2 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto



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<h2 style="margin: 0;">DECLARATION</h2>	<b>ADDITIONAL INVENTOR(S)</b> <b>Supplemental Sheet</b> Page <u>1</u> of <u>2</u>
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<b>Name of Additional Joint Inventor, if any:</b>				<input type="checkbox"/> A petition has been filed for this unsigned inventor			
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Howard				Bernstein			
Inventor's Signature	<i>Howard Bernstein</i>					Date	11-22-99
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Given Name (first and middle [if any])				Family Name or Surname			
Sarwat				Khattak			
Inventor's Signature	<i>Sarwat Khattak</i>					Date	11/22/99
Residence: City	Cambridge	State	MA	Country	USA	Citizenship	US
Post Office Address 98 Pine Street							
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## DECLARATION

ADDITIONAL INVENTOR(S)  
Supplemental Sheet  
Page 2 of 2

Name of Additional Joint Inventor, if any:

☐ A petition has been filed for this unsigned inventor

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Name of Additional Joint Inventor, if any:

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